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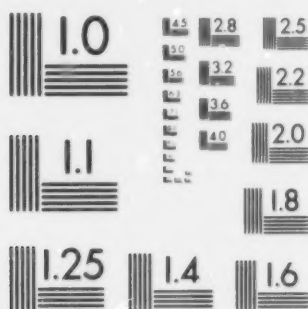


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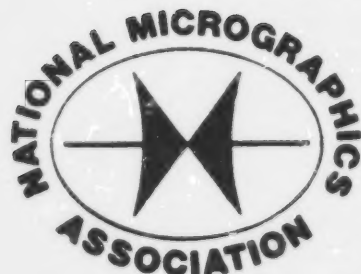
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MINERALS

ECONOMIC & REGIONAL DEVELOPMENT AGREEMENT

Final Report
TASK 4 - Geotechnical Database
for Ground Control
Numerical Model
QUAD USER MANUAL

by

Inco Limited, Thompson Division
Thompson, Manitoba

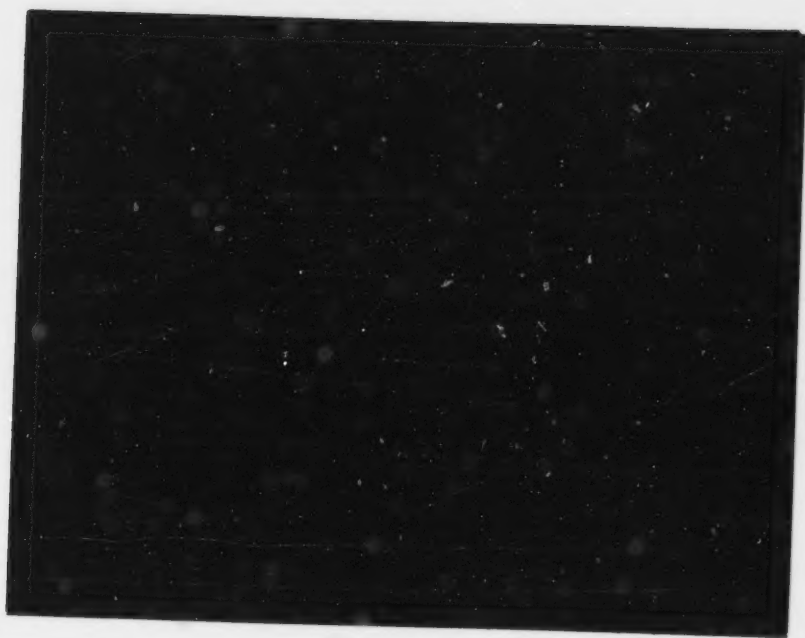
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CANADA - MANITOBA
MINERAL DEVELOPMENT AGREEMENT

RESEARCH & DEVELOPMENT IN MANITOBA MINES

Work on the project was conducted under the auspices of Canada Centre
for Mineral and Energy Technology, Energy, Mines and Resources Canada
under the Canada/Manitoba Mineral Development Agreement.

DSS File NO. 14SQ.23440-4-9147-4
DSS Contract Serial No. OSQ84.00404
CANMET Project NO. 4-9147-4
CANMET Scientific Authority: Y.S. Yu

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MINERAL DEVELOPMENT AGREEMENT
RESEARCH & DEVELOPMENT IN MANITOBA MINES

GEOTECHNICAL DATABASE FOR GROUND CONTROL

Numerical Model
Quad User Manual

This has been prepared as part of the
TASK 4
Geotechnical Database for Ground Control
of the
Canada/Manitoba Mineral Development Agreement
by

Steffen Robertson & Kirsten (B.C.) Inc.
Sub-contracting to
Inco Limited, Thompson Division, Manitoba
(Daniel Ouellette)

DSS File No.: 14SQ.23440-4-9147-4
CANMET Project No.: 4-9147-4
CANMET Scientific Authority: Y.S. Yu

TABLE OF CONTENTS

1.0	INTRODUCTION	1
1.1	How to install Quad	1
1.2	How to Run Quad	2
1.3	Hardware Requirements and System Limitations	3
1.4	The Keyword System	3
1.5	The Menu System	3
1.6	The File System	3
2.0	MODEL PREPARATION AND INPUT DATA	5
2.1	Preparation of the Model	5
2.2	Dividing the Model into Finite Elements	5
2.3	Numbering of Nodes and Elements	6
2.4	Input Data	6
2.4.1	Nodes and Elements	7
2.4.2	Material Properties	7
2.4.3	Stresses	8
2.4.4	Boundary Conditions	8
2.4.5	Joint Sets	9
2.4.6	Type of Model and Analysis to Perform	9
2.5	Summary of Model preparation	9
3.0	THE KEYWORD SYSTEM	10
3.1	Introduction	10
3.2	Summary of Useful Keywords	10
4.0	THE MENU SYSTEM	10
4.1	Main menu	10
0.1	Initialize Database for New Run	10
0.2	Data Preparation	10
0.3	Mesh Plot Preparation	11
0.4	Special Input/Control Options	11
0.5	Number Crunching	11
0.6	Print Results	11
0.7	Prepare Results for Plotting	11
0.8	Digitizer Utilities	11
0.9	Documentation and Help	11
0.10	Advanced Help	11
4.2	Sub-menu 1: Initialize database for new run	12
1.1	Initialize Everything for a New Analysis	12
1.2	Initialize Stresses, Forces, and Displacements	12
1.3	Initialize Displacements and Strains	12
1.4	Initialize Boundary Conditions	12

	1.6	Return to Main Menu	12
4.3		Sub-menu 2: Data preparation	12
	2.1	Read in Data File of Nodes and Elements	12
	2.2	Double Up a Mesh	13
	2.3	Convert a Mesh to an ASCII File for Backup/Editing	13
	2.4	Load Material Properties	14
	2.5	Return to Main Menu	14
4.4		Sub-menu 3: Mesh plot preparation	14
	3.1	Display Information about Elements and Nodes	14
	3.2	Prepare a Mesh for Plotting	15
	3.3	Prepare Boundary Conditions for Plotting	16
	3.4	Prepare Perimeters for Plotting	16
	3.5	Return to Main Menu	17
4.5		Sub-menu 4: Special input / control options	17
	4.1	Set a Linear Run	17
	4.2	Set a Non-Linear Run	17
	4.3	Set Plain Strain Analysis	17
	4.4	Set Plain Stress Analysis	18
	4.5	Set an Axi-Symmetric Analysis	18
	4.6	Increment the Current Step Number by 1	18
	4.7	Display the Number of Nodes, Elements, and Boundary Conditions	18
	4.8	Spare	18
	4.9	Return to Main Menu	18
4.6		Sub-menu 5: Number crunching	18
	5.1	Calculate Element Stiffness	19
	5.2	Check for Dead Nodes and Calculate Profile of Equations	19
	5.3	Assemble Equations	19
	5.4	Solve Equations	19
	5.5	Back Substitution	19
	5.6	Calculate Stresses and Strains at Elements	19
	5.7	Calculate Nodal Forces	19
	5.8	Check for Material Failure	19
	5.9	All of the Above under Batch Control	19
	5.10	Return to Main Menu	19
4.7		Sub-menu 6: Print results	20
	6.1	Print the Header Page	20
	6.2	Print Selected Element Geometry	20
	6.3	Print Material Properties	21
	6.4	Print Nodal Results	21
	6.5	Print Element Results	22
	6.6	Print Perimeter Information	22
	6.7	Print Mesh Input Data (Nodes and Elements)	22
	6.8	Print Elements for Each Sub-Region	23
	6.9	Spare	24
	6.10	Return to Main Menu	24
4.8		Sub-menu 7: Prepare results for plotting	24
	7.1	Prepare a Mesh Plot	24

7.2	Prepare Perimeters for Plotting	24
7.3	Prepare Element Results for Plotting	24
7.4	Prepare Nodal Results for Plotting	26
7.5	Prepare a Deformed Mesh for Plotting	27
7.6	Spare	28
7.7	Return to Main Menu	28
4.9	Sub-menu 8: Digitizer utilities	28
8.1	Set Up Digitizer and Plan Scales	28
8.2	Digitize Nodal Coordinates	28
8.3	Digitize the Nodes for Selected Elements	28
8.4	Digitize Nodal Boundary Conditions	28
8.5	Digitize Nodes Defining a Contour	28
8.6	Digitize Outlines for Plotting	28
8.7	Display/Check Node, Elements, and Boundary Conditions	28
8.8	Return to Main Menu	28
4.10	Sub-menu 9: Documentation and help	29
9.1	List Available Keywords for Data File Preparation	29
9.2	Spare	29
9.3	Return to Main Menu	29
4.11	Sub-menu 10 advanced utilities	29
10.1	Display/Check Selected Nodes/Elements	29
10.2	Display Element Information	30
10.3	Display Arrays in File QUAD.ARR	31
10.4	Display File Status and Switch Registers	32
10.5	Load in a New Message File	32
10.6	Display or Modify Messages	32
10.7	Print Out Messages	33
10.8	Return to Main Menu	33

LIST OF APPENDICES

Appendix A: QUAD MESSAGE FILE	A1 - A13
Appendix B: QUAD KEYWORDS	B1 - B84
Appendix C: QUAD EXAMPLES	C1 - C33

LIST OF TABLES

Table 1: Database structure of QUAD	34
Table 2: Contents of QUAD.ARR file	35
Table 3: Contents of QUAD.ELT file	36
Table 4: Contents of QUAD.MAT file	37
Table 5: Material type codes in array MTYP	37
Table 6: Contents of QUAD.STF file	38
Table 7: Contents of QUAD.FIL file	38
Table 8: Sub-menu 3, Option 1 output	39
Table 9: Non-linear material types and output parameters	39
Table 10: Choices for values to plot at elements	40
Table 11: Choices for values to plot at nodes	40
Table 12: Element numbering checker	41

LIST OF FIGURES

Figure 1: Illustration of Planes of Symmetry	42
Figure 2: Illustration of Planes of Symmetry with Geological Discontinuities	43
Figure 3: Example of a Mesh for a Circular Tunnel (Two symmetry)	44
Figure 4: Outer Mesh for Circular Tunnel	45
Figure 5: Non-linear Run, Original Mesh	46
Figure 6: Non-linear Run, Elements	47
Figure 7: Non-linear Run, Nodes	48
Figure 8: Hoek's Excess Stresses (Compressive Stress Value Returned)	49
Figure 9: Hoek's Excess Stresses (Tensile Stress Value Returned)	50
Figure 10: Mohr Coulomb Excess Stresses (Compressive Stress Value Returned)	51
Figure 11: Mohr Coulomb Excess Stresses (Tensile Stress Value Returned)	52

1.0 INTRODUCTION

Quad is a two dimensional finite element analysis program for plain stress and plain strain analysis. Quad uses linear triangular or quadrilateral elements for modelling. Axisymmetric three dimensional structures can also be analyzed. Structural systems which currently can be analyzed include:

- (i) Slopes and embankments
- (ii) Mining excavations
- (iii) Tunnels and underground caverns

Provision is made for linear or non-linear, isotropic or anisotropic as well as homogeneous or non-homogeneous material behaviour. Specific non-linear problems which can be modelled include:

- (i) Zero or low tensile strength material
- (ii) Mohr Coulomb shear strength material
- (iii) Material with one or more joint sets
- (iv) Linear or non-linear backfill
- (v) Post processor option to assess potential failure subject to Hoek's failure criterion (Hoek, 1983)

Loads or stresses can be applied to the nodes using one of the following methods:

- (i) Gravitational loading
- (ii) Point forces (loads) applied at selected nodal points.
- (iii) Stresses applied to line defined by specific nodes

The program also makes provision for excavation, construction, and incremental loading steps, its capacity is set at 1536 nodal points or elements.

In the hands of an experienced user the finite element method is a powerful design aid. However, in the hands of an inexperienced user it can be a disaster. The main reason for this is that it is unfortunately very easy to make mistakes in the input data file and to specify wrong values or codes for material properties, boundary conditions and so on. In spite of such errors the results may still appear to be realistic and the experienced user has a better chance to detect the erroneous results, and make corrections before the results are used, than the inexperienced user. Inexperience can also result in unnecessary errors which in turn can lead to additional runs which for a large mesh can be expensive in terms of man hours and computer time. It is therefore strongly recommended that an experienced user should always be consulted before embarking on such an analysis.

This manual is aimed at assisting the user with preparation of input data, running the program, and re-organisation of output data to facilitate interpretation and presentation of the results.

1.1 How to install Quad

The program Quad comes on one diskette. It should be installed on a hard drive, as it accesses many database files, and normal floppy disk drives will slow down a run too much. To install Quad on the hard disk, all files on the disks should be copied over.

First, Quad should have its own directory. If one is not already available on the hard disk, the user should create one.

As an example, say the user wishes to install Quad on the C: drive of the hard disk. To create a subdirectory for Quad, he/she would type at the DOS prompt `MKDIR C:\QUAD <return>`.

To install Quad into this directory, all files from the Quad disk must be copied to it.

To do this, place the QUAD floppy disk into the appropriate floppy disk drive. This will normally be disk drive A:. To copy the files, the user will type the following at the DOS prompt:

```
COPY A:\*.* C:\QUAD\*.* <return>
```

The DOS PATH should be modified to include C:\QUAD, so that the QUAD program may be ran from any other subdirectory.

1.2 How to Run Quad

To run Quad the following steps must be followed:

- 1) Set up data files.
- 2) The system disk for Quad should be in drive A:. The files QUAD.FIL, DIG.FIL, DIGIT.FIL and QUAD.MES are to be on this disk. In addition, if quad is being ran for the first time from subdirectory, then the batch file NUQUAD.BAT should be ran to create working QUAD file in this subdirectory.
- 3) If a digitizer is going to be used during a run, then it must be set up with the DOS MODE statement. Refer to a DOS manual for further details on how MODE works.
- 4) The user should be in the Quad subdirectory. From here, type `QUAD <return>` at the DOS prompt to enter the program.
- 5) A introduction screen will appear, press `<return>` to clear it.
- 6) Quad then asks for the name of a data file. This is where the two forms of control come in. If the user types `MENU <return>` for the data file name, Quad enters the interactive menu system. If the user supplies a file name, Quad enter the keyword system, and assumes the data file contains keywords to perform a run. This data file contains:
 - i) Control data to specify what the program must do, the numbers of elements and nodes, the type of analysis to be performed
 - ii) Loads and stresses to be applied to the model
 - iii) Coordinates of all nodes
 - iv) Specification of nodes around each element
 - v) Material properties
 - vi) Boundary conditions
- 7) Once the session with Quad is done, the user will exit from Quad. This is done with the keyword `STOP` or by choosing the menu option 0 (for stop).

1.3 Hardware Requirements and System Limitations

The minimum requirements for Quad are

- an IBM PC, XT, AT, PS/2 or compatible
- at least 512 k of RAM
- DOS 2.0 or higher
- at least one double sided disk drive
- a hard drive with at least 5 MBytes of free space
- a printer or plotter for output

As the files used by Quad take up a fair amount of room, a hard drive of at least 10 mega bytes is suggested. Digitizing is often a useful option, so a digitizer is also suggested hardware.

The program and its associated files take up about 2½ to 3 mega bytes or up to 5 or 6 MBytes for larger problems.

The running time of Quad varies depending on the size of the mesh and the type of analysis being done. For an average mesh of about 400 elements and linear analysis, Quad takes about 25 minutes to run. For larger files, it may take days to run Quad. Also, non-linear analysis takes longer than linear analysis, so this should be taken into account when doing a run.

1.4 The Keyword System

Quad can be controlled through an input data file containing keywords. These keywords control the flow of the program, and the input of information for a run. A summary of major keywords and their use follows this introduction. A listing of all keywords appears in APPENDIX B.

1.5 The Menu System

Quad can be controlled through an interactive menu system. This system allows the user full control of inputting data, performing runs, and making output from Quad. A comprehensive summary of all menus in the menu system follows this introduction.

1.6 The File System

Preparation of input for a finite element analysis is often a tedious process. A mesh has to be drawn up (or generated using a mesh generator). Thereafter, material properties have to be assigned to different groups of elements. Nodal boundary conditions have to be defined as well as load conditions. It is also usual to prepare various plots of the input data for data checking.

In the previous versions of Quad, many of the above processes were carried out by different programs, each with its own input and output files. This resulted in numerous files being handled by the user with the resulting increased chances of data errors. The new database structure was aimed to alleviate this problem by having one unified database for mesh, boundary conditions and material properties. Each program module adds to or modifies the main database. The next paragraphs describe some aspects of the database structure.

One reason for splitting the database into several smaller files is that when programs are run on an IBM-PC/AT or compatible computer, it is sometimes desirable to put some of the files onto a virtual disk or ramdrive. By doing this, the overall execution time of some problems can be speeded up considerably. Another reason for having the database stored on many files is that when several runs are carried out, it may not be necessary to backup all files for every run. For example, the global stiffness matrix file only changes when material properties or displacement boundary conditions are changed. In this manner, storage requirements for backups are reduced.

Database file names and a description of the purpose of each file are presented in Table 1. It should be noted that the channel numbers are primarily for internal program usage and are not of direct concern to the user. The global stiffness file QUAD.STF is the largest of all the files, taking over a mega byte of disc storage for an average run.

The next few paragraphs explain the structure of some of the database file used by Quad.

The file QUAD.ARR contains various arrays used internally by Quad. The contents of the file are shown in Table 2. Some of the various arrays can be accessed by advanced users to follow exactly what is happening in complex multiple step runs.

The file QUAD.ELT contains various information relating to element geometry. Its structure is shown in Table 3.

The file QUAD.MAT contains information relating to the material properties of elements. Its structure is shown in Table 4. The array MTYP for material types contains information relating to material types available to a single element. Explanation of this information code is found in Table 5.

The file QUAD.STF contains the element stiffness information. Its structure is given in Table 6.

Another file used by Quad is the QUAD.FIL file on the systems disk. This file is outlined in Table 7. This file is the format file for controlling Quad. Priority for putting files onto virtual disk should be (depending upon available virtual disk space) :

- | | |
|----|----------|
| 1) | QUAD.ELT |
| 2) | QUAD.MAT |
| 3) | QUAD.ELT |
| 4) | QUAD.ARR |

Other files may be on any drive/directory, but should be grouped together.

Note that line 10 in Table 7 is the input data filename or USER for interactive entry of the data filename.

Also note that line 12 is LPT1 for direct printing or TEMP.LST for printing to a disk file first (TEMP.LST is preferred).

2.0 MODEL PREPARATION AND INPUT DATA

Before the preparation of the input data is described, it is necessary to deal briefly with the preparation of the model and dividing the model into finite elements. It is only after the mesh of finite elements is completed that the full data file can be prepared.

2.1 Preparation of the Model

The first step in any finite element analysis is to define the model to be analyzed. This involves drawing the outline of the structure to be analyzed and regions with different material properties to scale on a piece of graph paper. This must be a fairly accurate representation of the structure.

At this early stage it is important to recognise planes of symmetry in the model because if these are present, the extent of the model and the number of elements may be reduced with a considerable saving in the preparation time and computer costs.

Typical examples to illustrate the use of planes of symmetry are shown in Figure 1. Figure 1a shows a model of a circular tunnel. It is not necessary to model the complete tunnel because of the two planes of symmetry. Only a quarter of the tunnel and surrounding rock need be modelled as shown. Another tunnel with one plane of symmetry is shown in Figure 1b. In this case, only half of the structure need be modelled. Figure 1c illustrates an excavation with no planes of symmetry. The complete structure must be modelled here.

It is important to note that any plane can only be treated as a plane of symmetry if the following requirements are satisfied.

- 1) The model must be symmetrical on either side of the plan with respect to shape.
- 2) It must also be symmetrical with regard to geology (material properties)
- 3) In addition it must be symmetrical with respect to the applied loads or stresses.

Examples are given in Figure 2. It is important to note that at all nodal points on a plane of symmetry, displacement normal to the plane should be prevented. This is done by specifying the appropriate code for the nodal points as will be explained later.

2.2 Dividing the Model into Finite Elements

To keep the explanation simple it is assumed that the process of dividing up the model will be done manually.

The model has to be divided into finite elements using four node quadrilateral elements or three node triangular elements. Both elements types have the property that straight lines joining adjacent nodes will remain straight during loading and deformation of the model. There will of course be a change in the length of the lines. This simple fact is of great importance in deciding on the number and size of the elements to be used. If the stress and displacement gradients are small (ie. stresses are equally distributed) a few large elements will give satisfactory results. However, if the gradients are high, for example in the vicinity of an excavation or soft geological layer, then a large number of smaller elements should be used. The following basic rules should be adhered to:

- 1) Quadrilaterals should be used in preference to triangles because the results are more accurate.
- 2) Elements should be as close as possible to equilateral triangles and squares. The length to width ratio should be less than 1:5.
- 3) Interior angles of quadrilaterals should not exceed 160 degrees.
- 4) Use a minimum of three rows of elements for a geological region such as that shown in Figure 2.
- 5) A maximum of 1536 elements is allowed. However, running costs are proportional to the number of elements (and nodes). The number of elements should be kept as small as possible but without sacrificing an accurate representation of the structure and geology.
- 6) Large elements next to small elements induce inaccuracies. Keep to a maximum ratio of 4 to 1. Increase element sizes gradually as you move away from the zone of high stress gradients.
- 7) A node which divides the side of any element is not allowed

2.3 Numbering of Nodes and Elements

For simplicity sake, only the case of manual node and element numbering is dealt with. After preparation of the mesh all nodes and elements should be numbered. The following basic rules apply:

- 1) Element numbering has no restrictions. However, it makes specification of element properties easier if numbering is arranged to consecutively cover geological subregions. Refer to Figure 3 for an example.
- 2) Node numbering must be done in such a way as to obtain the minimum bandwidth. The bandwidth is the difference between node numbers across any element. The maximum value allowed is 256. Refer to Figure 4 for an example.

The application of the basic rules can be illustrated by means of an example. The tunnel model in Figure 1a should be modelled with small elements near the tunnel with a gradual increase in size with distance from the tunnel. A suitable mesh splits into two portions as shown in Figures 5 and 2.6. One suitable method of numbering nodes and elements is illustrated in these Figures. There are many other possibilities and sequences that can be used as long as the basic rules are adhered to.

In many cases it is not necessary to prepare the mesh by hand and do the numbering manually. Quad has a digitizing facility, which allows the user to input the mesh directly into the computer.

2.4 Input Data

After completion of the mesh and numbering of the nodes and elements, the next step is to prepare the input data file and to get these files into the computer. There are a number of options in Quad to assist the user and these are described later in the Keyword and Menu system sections of the manual. At this stage, it is assumed that everything will be done manually.

The input files will contain information on various things, all of which are used by Quad to define the model. The input files will contain information such as:

Control data to specify what the program must do, the number of elements and nodes, the type of analysis to be performed, and so on.

Loads and stresses to be applied to the model.

Coordinates of all nodes

Specification of nodes around each element

Material properties

Boundary conditions

etc..

For Quad to run properly, information about the model must be stored and available to the program. In the paragraphs to follow in this section, this information will be explained.

2.4.1 Nodes and Elements

The data file must contain information on the nodes and elements that make up the model. This information was created and explained above.

The information that must be stored for nodes is the node number, and its coordinates. Coordinates should be in meters.

ie Node Number, X-coordinate, Y-coordinate

Information stored for the elements are its number and the node numbers that make up the element.

ie Element Number, Node 1, Node 2, Node 3, Node 4

The general rule is to specify the four nodes in an anticlockwise sense around the element. As an example, refer to Figure 6. Element 1 would be defined as follows:

1, 17, 2, 1, 18

There are two ways to define a triangular element. One way is to define Node 4 to be equal to Node 3. The other is to specify Node 4 to be 0.

2.4.2 Material Properties

The user must store information in the file about the material properties of the various subregions that make up the model. The file contains the definitions of the properties plus which elements have what properties.

The material properties definitions tell Quad what each subregion is like.

For a complete description of what variables are to be defined, refer to the keyword MATP in Appendix B.

Briefly, for each subregion, several variables are set for the material properties. The first set of variables are the density, Young's modulus, Poisson's ratio, anisotropic Young's modulus, shear modulus and Poisson's ratio, and the default anisotropic angle. The second set of variables are the material property code, as shown in Table 5, and various properties for non-linear materials.

2.4.3 Stresses

Stresses are another set of information that must be included in the input data file. Stresses can be defined in several ways. These are :

- Constant and depth dependent stresses
- Gravity
- Stresses around a perimeter

Constant stresses are stored in the variables PXX, PYY, PXY. Depth dependent stresses are stored in the variables DXX, DYY, DXY. Stresses are in MPa. The sign convention for Quad is that compressive stresses are negative values, and tension being a positive values.

Gravity loading may be added by the program; the user need only specify in the data file that it is to be added.

Stresses around a perimeter are very useful. Perimeters are defined in the input file by giving them a name, a number, and a list of the nodes that define the perimeter.

ie Perimeter Name
Perimeter Number, List of Nodes in Perimeter.

Stresses then can be placed around the perimeter. Its usefulness is that these stresses can be independently defined of all the other stresses in the model. See keywords PERI and EX in Appendix B for more information on perimeters and defining stresses on them.

2.4.4 Boundary Conditions

Boundary conditions are the next set of information that should be found in the input data files. These conditions allow for special treatment of nodes. They can specify that some nodes have limited movement allowed, and that others may have extra forces other than stresses placed on them.

Conditions are stored in the data files in the following manner. First is the node the condition is to act upon, then the condition code, followed by two values, one for an X force or displacement, the other for a Y force or displacement. The condition code determines what the given X and Y values are.

ie Node, Condition Code, X force/displ., Y force/displ.

A condition code equal to 1 means that an X and Y force are specified. Condition code of 2 means apply an X force and Y displacement. Condition code of 3 means apply an X displacement and Y force. A condition code of 4 means apply an X and Y displacement specified.

2.4.5 Joint Sets

If joint sets are to be modelled, their definitions must appear in the input data files. It is always difficult to obtain input data for any joint modelling exercise. Therefore, the required input data has been deliberately minimized in the interest of simplicity and practicality. The following variables are required as input for a give joint set:

- Cohesion of the joint set
- Angle of friction of the joint set
- Tensile strength of the joint set
- Orientation of the joint set
- Continuity of the joint:
 set(1 = continuous, 0 = discontinuous)
- Dilatancy factor
- Residual cohesion of the joint set once it has failed.

For more information on joint sets, refer to the keyword JOINT in Appendix B.

2.4.6 Type of Model and Analysis to Perform

The model will be either linear or non-linear. The input data file must specify which. If a non-linear run is specified, the data file must also contain information on how the run is to be performed. The file must contain the following:

- Maximum number of non-linear iteration to run
- Acceleration factor
- Convergence limit

A non-linear run may take a long time and a large number of iterations to complete. By specifying the maximum number of iterations in a run, it cuts down on the time that may be needed to perform a run.

There are three types of analysis that can be performed. Which one is to be used must be specified in the input data. The three types of runs are:

- Plain strain analysis
- Plain stress analysis
- Axi-symmetric analysis

Most analyses are of the type plain strain.

2.5 Summary of Model preparation

Once the model has been defined, and the input data is stored in a file, the user can run Quad to perform an analysis of the model. As stated in the section on running Quad, there are two ways to run Quad. The first is through keyword control, and the second is through menu control. Keywords control is suggested for input of data and basis running of the program, whilst menu control is suggested for post-processing.

3.0 THE KEYWORD SYSTEM

3.1 Introduction

As different users have different requirements for the system, input is made none flexible by means of keywords. Keywords are used, then, to separate various sections of input data which may be in one or many data files. The order in which keywords are input is important in many cases. For example, NODES and ELEMENTS must be defined before the RUN keyword is used. Experience and the various examples supplied should indicate reasonable ordering for most keywords. The following pages contain detailed descriptions and summaries of the various keywords which have been programmed into QUAD.

3.2 Summary of Useful Keywords

See Appendix B.

4.0 THE MENU SYSTEM

Quad can be controlled through a series of interactive menus. These menus allow the user total control over how Quad takes in model data, analyses data, and outputs data. The following sections describe in detail the menus and their sub-menus.

Note: The numbers in front of each part are the menu option number. For example, 1.1 stands for sub-menu 1, option 1.

Note: In any menu, there is an option 0. This option stops the program. This should be used at the end of a run to stop the program.

4.1 MAIN MENU

Once Quad has started, and the menu system is chosen, this is the first menu to appear. The main menu controls the overall operation of Quad, with each of its sub-menus controlling smaller parts of the input, analysis, and output of data. Each of the sub-menus are briefly described in the sections to follow. A more in depth discussion of each will follow this portion of the manual.

0.1 Initialize Database for New Run

Sub-menu 1 allows the user to initialise either the whole database, or specific parts of the database. The whole database is initialised every time a new model is to be looked at. Initialising specific parts of the database is useful when performing multiple step runs. For each step of the run, a part of the database can be initialised, then the appropriate data read into that section of the database. This allows the user to change various parts of the database without changing the entire database.

0.2 Data Preparation

Sub-menu 2 is used to prepare the input data of a run. It can read in the node, element, and material properties in from a file. It also allows the user to double up a mesh. This breaks every quadrilateral element

into four (4) elements, and every triangular element into three (3) elements. This is useful for creating finer meshes for a run. This sub-menu also can output the current mesh to an ASCII file for easy backup or further editing.

0.3 Mesh Plot Preparation

Sub-menu 3 allows the user to output the mesh, boundary condition and perimeters to plot files. It also allows the user to view information about the nodes and elements that make up the mesh.

0.4 Special Input/Control Options

Sub-menu 4 is used to control the type of analysis that is to be performed on the model. It allows the user to choose between linear and non-linear runs, and plain strain, stress or axisymmetric analysis. It also is used in multiple step runs, allowing the user to increment the current step of the run. It finally lets the user view the current nodes, elements, and boundary conditions.

0.5 Number Crunching

Sub-menu 5 controls the number crunching aspect of Quad. This allows the user control over how the actual analysis is calculated.

0.6 Print Results

Sub-menu 6 controls the printing of information from Quad. It allows the user to print such things as the original data before the run, and the data calculated by Quad.

0.7 Prepare Results for Plotting

Sub-menu 7 puts the results calculated by Quad into plot files that can be plotted with other programs. (eg GEMPLOT available from Gemcom Services Inc., no readily available alternatives.) Some options are to plot element results, nodal results, and the deformed mesh calculated by Quad.

0.8 Digitizer Utilities

Sub-menu 8 allows the user to use a digitizer to input node, element and boundary condition information. This is a useful option, as it can save the user the time and effort needed to manually calculate the positions of the nodes. It also save him the time needed to key in all the data into the computer.

0.9 Documentation and Help

Sub-menu 9 supplies help and information on keywords to the user.

0.10 Advanced Help

Sub-menu 10 allows the user to interactively view some of the variables used by Quad. This is useful in debugging the model. This option also allows the user to view, modify, and print the current message file.

4.2 Sub-menu 1: Initialize database for new run

Sub-menu 1 controls the initializing of the Quad data base for new runs. The data base consists of several files. These files are shown the first part of Table 1. This menu allows the user to initialise all files (for a new model), or some of the files (for a multiple step analysis).

1.1 Initialize Everything for a New Analysis

Sub-menu 1, Option 1 clears all files in the data base.

1.2 Initialize Stresses, Forces, and Displacements

Sub-menu 1, Option 2 clears stresses, force and displacements. These variables are stored in the QUAD.ARR and QUAD.ELT files. This is useful for multiple step runs. It allows the user to blank out these values, and then later input new values for them. This allows the user to only change these variables, without changing the rest of the data base.

1.3 Initialize Displacements and Strains

Sub-menu 1, Option 3 clears the displacement and strain variables stored in the data base. As in Option two, this is useful for multiple step runs.

1.4 Initialize Boundary Conditions

Sub-menu 1, Option 4 sets all boundary conditions found in QUAD.ARR to zero. This way, the user can later specify new boundary conditions for a multiple step run.

1.5 Display Valid Keywords for Use in Input Data File

Sub-menu 1, Option 5 will display on the screen all valid keywords used by Quad. An edited listing of this display is found at the front of Appendix B.

1.6 Return to Main Menu

Sub-menu 1, Option 6 returns the user to the main menu so he/she may continue on with the current run.

4.3 Sub-menu 2: Data preparation

Sub-menu 2 is designed to give the user interactive control of the input data of a mesh for a given run. It is currently better and strongly recommended for the user to use keywords at this stage, since they offer more flexibility and are less likely to result in user input errors.

2.1 Read in Data File of Nodes and Elements

Sub-menu 2, Option 1. This allows the user to get a data file containing node and element information into the Quad program for analysis. When the option is selected, the program prompts the user for the name

of the data file to use. The data file will look like a partial keyword file, made up of only the keyword NODE, the nodal information, the keyword ELT, and the element information. Refer to the keywords NODE and ELT in Appendix B for more information. The general format of the file will be

NODE

Number of nodes

Node number, X-coordinate, Y-coordinate of node

Node number, X-coordinate, Y-coordinate of node

etc.

ELT

Number of elements

Element number, Node 1, Node 2, Node 3, Node 4

Element number, Node 1, Node 2, Node 3, Node 4,

etc.

Elements are of two types: quadrilateral (4 sided) and triangular (3 sided). The general rule is to specify the four nodes in an anticlockwise sense around the element. As an example, refer to Figure 6 and 7. Element 1 would be defined as follows:

1, 1, 12, 13, 2

There are two ways to define a triangular element. One way is to define Node 4 to be equal to Node 3. The other is to specify Node 4 to be 0.

Note: The data file containing the node and element information can have other keywords within it. Quad is able to locate the information and extract it from the data file. In this way, a full keyword input file can still be used with menu control.

2.2 Double Up a Mesh

Sub-menu 2, Option 2. Doubling up of a current mesh can be useful, as it creates a finer mesh, and results from Quad will be more accurate. When this option is chosen, the program prompts for a point to start re-numbering the nodes from. Nodes will be renumbered such that nodes closest to the above point have the lowest numbers, and points farthest away have larger numbers.

Doubling of a mesh has the following affect on elements. Quadrilateral elements are split into four (4) elements. The new nodes for these elements are the centre of the original element, and the midpoints along each of the sides of the original element. Triangular elements are split into three (3) new elements. The new nodes created for these elements are the centre of the original element, and the midpoints along each of the sides of the original element.

2.3 Convert a Mesh to an ASCII File for Backup/Editing

Sub-menu 2, Option 3. This takes the current mesh and converts it into node and element information. This information is then stored out to disk for backup purposes, or for further editing. The file contains the node information first, and then the element information. The format of the output is:

Node number, X-coordinate, Y-coordinate
Node number, X-coordinate, Y-coordinate
etc.

Element number, Node 1, Node 2, Node 3, Node 4
Element number, Node 1, Node 2, Node 3, Node 4
etc.

2.4 Load Material Properties

Sub-menu 2, Option 4. This loads the material properties of the elements into Quad. The information is stored in a data file that looks like a keyword data file. The data file must contain the keyword MATP, the material properties of each subregion, the keyword MATEL, and a list of which elements have which property. Refer to keywords MATP and MATEL in Appendix B for more details.

The general format of the input file is:

MATP

- Number of Subregions
- Description of subregion
- Subregion Number, Unit Weight, Young's modulus, Poisson's ratio, anisotropic Young's modulus, shear modulus, and Poisson's ratio, and the default anisotropic angle.
- Material type code (as shown in Table 5), five non-linear variables, and the plotter pen to use for this subregion.

When a linear run is specified, the five non-linear variables are all set to zero.

The plotter pen can have a value between one (1) and four (4).

2.5 Return to Main Menu

Sub-menu 2, Option 5. Returns the user to the main menu.

4.4 Sub-menu 3: Mesh plot preparation

The purpose of sub-menu 3 is to output information about the model to plot files. It can output the mesh, boundary conditions, and perimeters used to define the model. It also has the option to display information about the number of nodes and elements that make up the mesh.

3.1 Display Information about Elements and Nodes

Sub-menu 3, Option 1. This option displays to the screen information about the model. Refer to Table 4.4.1 for an example output.

In brief, this option prints the following information:

- Number of nodes and elements
- Number of material types defined

- Type of analysis, being plain strain, stress or axisymmetric
- Constant stresses
- Depth dependant stresses
- Which type of run is to be performed, linear or non-linear. If the run is non-linear, information on the maximum number of iterations, acceleration factor and convergence limit are also printed.

3.2 Prepare a Mesh for Plotting

Sub-menu 3, Option 2. This option is used to output the mesh to a plot file. The user also has the option to save node and element numbers out to plot files. Saving the numbers out is useful as a backup of what nodes and elements are where for easy reference. The mesh is stored in the plot file QUAD.PM. Node and element numbers are stored in plot files QUAD.PN and QUAD.PE respectively. These files can then be viewed or plotted with other programs.

The following actions are performed when the user selects this option.

- 1) The user is first prompted about how node information is to be saved.
 - a) The program prompts the user for the plotter pen colour to use in plotting node information. The user has two options. Option 0 will select no pen colour. Option 1 will let the user select the pen colour later in the program. Select Option 0 if node information is not to be plotted.
 - b) The program then prompts for how node information is to be plotted. There are three options. Option 0 will plot nothing at the nodes. Option 1 will plot the node number at the nodes. Option 2 will plot an X at the nodes.
 - c) If option 1 or 2 is selected in 1b, the program prompts for which nodes to display information at. This option allows the user to choose all the nodes or a subsection of nodes.

The maximum number of nodes is displayed on the screen. The user is prompted for the first and last node in a series to send to the plot file.

To select all nodes, the user will enter 1 and the maximum number of nodes at the prompts. To select a subset, the user will answer with the node numbers he wishes to plot.

The program will go to step 1d to select the colour of the pen if the user chose to select the colour, then it will store the node information in QUAD.PN.

The program will continue to ask for first/last pairs of nodes. It will stop once the last node prompt is equal to the maximum number of nodes, or when a value of -99 is entered for either of the prompts.

- d) The program prompts the user for the plotter pen colour if he chose in 1a to select the pen colour. The user can choose pen number 1 to 4. If the user chose to not select a pen colour, this prompt is skipped.
- 2) The user is now prompted how element information and the mesh is to be plotted out.

- a) The program prompts for how pen colours are to be selected. The user has three options. Option 0 will select no colour. Option 1 will allow the user to select the pen colour interactively. Option 2 will take the pen numbers defined in the material properties. Note, this option affects the colour of element information and what colours the mesh will be.
- b) The next prompt is for the shrinkage factor of elements. This is useful in that it allows each element to be clearly separated from its neighbours. It also allows the user to leave space for where node information is to be placed. The user should enter value between 0.7 (for small elements) to 1.0 (for actual size elements).
- c) If option 1 or 2 is selected in 2a, the program prompts for which elements to display information at. This option allows the user to choose all the elements or a subsection of elements.

The maximum number of elements is displayed on the screen. The user is prompted for the first and last element in a series to send to the plot file. To select all elements, the user will enter 1 and the maximum number of elements at the prompts. To select a subset, the user will answer with the element numbers he wishes to plot.

The program will go to step 2d to select the colour of the pen if the user selected interactive colour selection, then it will store the element information in QUAD.PE. The element of the mesh is stored to the QUAD.PM file.

The program will continue to ask for first/last pairs of elements. It will stop once the last element prompt is equal to the maximum number of elements, or when a value of -99 is entered for either of the prompts.

- d) The program prompts the user for the plotter pen colour if he chose in 2a to select the pen colour. The user can choose pen number 1 to 4. If the user chose to not select a pen colour, or chose to use the pens defined by the material properties, this prompt is skipped.

3.3 Prepare Boundary Conditions for Plotting

Sub-menu 3, Option 3. This options plots out the boundary condition code at the nodes where they are defined. The boundary conditions are stored in the plot file QUAD.PN for easy plotting.

The following actions are performed when the user selects this option:

- 1) The user is prompted about how to plot the boundary condition. There are three options. Option 0 is to plot nothing. Option 1 is to plot the boundary condition codes at the nodes they are defined at. Option 2 is to plot an X at the node the condition code is defined at.
- 2) The program then prompts for the plotter pen colour to use. The pen numbers are in the range of 1 to 4. After the choice is made, the program stores the boundary condition information to the file QUAD.PN.

3.4 Prepare Perimeters for Plotting

Sub-menu 3, Option 4. This options will output selected perimeters to a plot file. Information is stored in the QUAD.PP file. Perimeters are stored as a series of lines connecting each of the nodes that define them.

The following actions are performed when the user selects this option:

- 1) The program prompts for the pen colour to use in plotting the perimeter. The pen values range from 1 to 4.
- 2) The program then prompts for which perimeters to plot to QUAD.PP. Displayed on the screen is the total number of perimeters defined. The program asks for the first and last perimeters in a series to plot. To plot all perimeters, enter 1 and the total number of perimeter at the prompts. To plot a single perimeter, enter the same number for both prompts. To plot no perimeter, enter -99 at any of the two prompts.
- 3) The program then saves the selected perimeters to the plot file QUAD.PP. The program then prompts if more perimeters are to be plotted. The user should answer Y for yes or N for no. If yes, the program goes back to step 1, otherwise the program returns to Sub-menu 3.

3.5 Return to Main Menu

Sub-menu 3, Option 5. This returns the user back to the main menu. It allows for further processing in Quad to be done.

4.5 Sub-menu 4: Special input / control options

Sub-menu 4 contains several input and control options. It allows the user to interactively set which type of run is to be performed, be it linear or non-linear. It allows the user to select which type of analysis, be it plain strain, stress or axisymmetric, is to be performed. It is also used to increment the step counter in a multiple step run.

4.1 Set a Linear Run

Sub-menu 4, Option 1. This option is used to set the type of run to be performed on the model to a linear run. The advantage to a linear run is that it is faster than non-linear runs, and is easier to understand. The disadvantages is that not all models can be made linear, and non-linear runs must be done.

4.2 Set a Non-Linear Run

Sub-menu 4, Option 2. Selecting this option makes the current run a non-linear one. Once selected, the program assumes the default non-linear variables of maximum number of iteration, acceleration factor, and convergence limit. For most cases, these defaults will work fine. To change these values, the user must use the keyword system and the keyword NONI. Refer to the keyword NONI in Appendix B for further information.

4.3 Set Plain Strain Analysis

Sub-Menu 4, Option 3. This option selects plain strain analysis as the type of analysis to be performed on the run.

4.4 Set Plain Stress Analysis

Sub-Menu 4, Option 4. This option selects plain stress analysis as the type of analysis to be performed on the run.

4.5 Set an Axi-Symmetric Analysis

Sub-Menu 4, Option 5. This option selects axi-symmetric analysis as the type of analysis to be performed on the run.

4.6 Increment the Current Step Number by 1

Sub-menu 4, Option 6. This option is used with multiple step runs. Before this option is selected, the user will probably have initialised various parts of the data base with options from sub-menu 1. After selecting this option, the next step would be for the user to set the data base sections reset above.

4.7 Display the Number of Nodes, Elements, and Boundary Conditions

Sub-menu 4, Option 7. Selecting this option will display to the screen information on various aspects of the model being studied.

It will display the following:

- Number of nodes
- Number of elements
- Number of different material types
- Number of nodes with boundary conditions set
- Number of perimeter/contour defined

4.8 Spare

Sub-menu 4, Option 8. This is a spare option. It is not used in the this version of Quad, and is reserved for future use with updated version of the program.

4.9 Return to Main Menu

Sub-menu 4, Option 9. This returns the user back to the main menu where he may proceed with further use of Quad.

4.6 Sub-menu 5: Number crunching

The options contained in this menu are ran consecutively using the single keyword RUN (see appendix B). In some instances, the user may wish to run some, but not all on these options. In such cases, the keyword

Run would be removed from the input / control data file and individual options from menu 5 would then be selected by the user (usually, however, the user need not ever use this sub-menu).

5.1 Calculate Element Stiffness

This calculates the "stiffness" for each element and store the results in file QUAD.EST.

5.2 Check for Dead Nodes and Calculate Profile of Equations

Useful checks are carried out to test the mesh for illegal node or element definitions. If possible errors are detected, the warnings are displayed which should be checked by the user.

5.3 Assemble Equations

Element stiffness from file QUAD.EST are assembled together to form the global stiffness matrix which is stored in file QUAD.STF.

5.4 Solve Equations

A matrix inversion of the global stiffness matrix is performed. This is also stored in file QUAD.STF.

5.5 Back Substitution

Displacements are found by back substitution from the current (applied) forces at each node.

5.6 Calculate Stresses and Strains at Elements

Based on the displacements at each node obtained from 5.5, incremental stresses and strain at each element are calculated.

5.7 Calculate Nodal Forces

Based on the displacements at each node, nodal forces and reactions are calculated for selected boundary nodes.

5.8 Check for Material Failure

If a non-linear run has been requested, then each element is checked for material failure. If failure is detected, then equivalent forces would be calculated and program control would revert to 5.5 for another iteration.

5.9 All of the Above under Batch Control

Runs 5.1 to 5.8 as though under batch control.

5.10 Return to Main Menu

4.7 Sub-menu 6: Print results

Sub-menu 6 prints out various results from Quad. It can be used to print out input data information, and output information calculated by the program. Refer to printed output section of the example run in Appendix E for more information and example output. The program prints the information out to a printer or to a file, whichever was defined in the QUAD.FIL file. See Table 7 for more information about the how to choose where printouts are sent. In the following paragraphs, output will be described independently of where it is being sent.

6.1 Print the Header Page

Sub-menu 6, Option 1. This selection prints out header information and a summary of the model being used.

The following information is printed out:

- User description of the model and run being performed
- Number of nodes and elements in the model
- Number of different material types
- Number of boundary condition nodes
- Number of perimeters defined
- The current mining step (useful in keeping track of mining step for multiple step mining runs.)
- Constant and depth dependant stresses
- What type of run is to be performed, linear or non-linear. If the run is non-linear, additional information on the maximum number of iterations, acceleration factor, and convergence limit is printed.

6.2 Print Selected Element Geometry

Sub-menu 6, Option 2. This option prints out information about selected elements. The information is for the elements before any analysis was performed on them.

Elements to be printed out are selected through the SKIP keyword. This keyword allows the user to select all or some of the elements for use in printouts. The user should note that there is no way of selecting nodes for skipping through the menu system. Skipping some elements may be useful when only certain elements are of interest to the user, and the rest are of less concern. It is also a way of cutting down on the size of output created. Refer to keyword SKIP in Appendix B for more information.

The information printed out for each selected element is:

- Element number
- Nodes that make up the element
- X and Y coordinate of the centre of the element
- Area of the element
- Primitive stresses in the X, Y, and XY shear directions.

6.3 Print Material Properties

Sub-menu 6, Option 3. Selecting this option will print information on the material properties defined in the model.

The printout comes with three lines of information. The first line is printed for all material properties, the second only if the material is not linear, the third if the material is anisotropic. Refer to example printouts in Appendix E for samples. Table 9 shows descriptions of non-linear material types and what parameters are printed out for each type.

The output printed by this option is:

Line One (for all material properties)

- Material property number
- Description of the material
- Young's modulus
- Poisson's ratio
- Density (unit weight)
- Plotter pen used for this material

Line Two (for non-linear material properties only)

- Description of non-linear material type
- Description of non-linear parameters to follow
- Non-linear parameters described in the line above

Line Three (for anisotropic material properties only)

- Statement that material is anisotropic
- Description and values of anisotropic variable values. (ie. the values of the anisotropic Young's modulus, shear modulus, and Poisson's ratio)

6.4 Print Nodal Results

Sub-menu 6, Option 4. This option prints out information on node results. It should be used after number crunching on a model has been run. It is useful in that it shows how nodes have moved and what stresses have been induced on them.

After selecting this menu option, the following is printed out for each node:

- Node number
- X and Y coordinates of the nodes as it was defined at the start of the model
- Boundary condition code, if any, at the node. Values for this code 0 for no boundary condition, and 1 to 4 for boundary condition with X and Y force/displacement specified.
- Nodal forces FX and FY in the X and Y directions, respectively
- Displacements U and V of the nodes in the X and Y directions, respectively
- Exponent form of the displacements above

6.5 Print Element Results

Sub-menu 6, Option 5. This option will print results of the selected elements. This option should be run only after a number crunching analysis has been performed on the model.

Print out for each element is as follows:

- Element number
- X and Y coordinate of the centre of the element. This centre coordinate is the one before an analysis was done on the model.
- Displacement U and V in the X and Y direction, respectively, of the centre of the element
- Strains in the X, Y, and shear XY directions
- Calculated stresses in the X, Y, and shear XY directions
- Calculated major and minor principal stresses and their orientations. The orientations are in degrees.
- Under the heading of NON is the non-linear material type code. Refer to Table 5 for more information on the code number returned.

6.6 Print Perimeter Information

Sub-menu 6, Option 6. This option prints information on all perimeters defined in the model. Note, perimeters can only be defined through keyword control. Refer to the keyword PERI in Appendix B for more information.

The format of the printout is as follows:

- The first line prints the number of perimeters defined

The following lines of information are printed out for each of the perimeters defined:

- The first line is the perimeter number and the number of nodes that define the perimeter
- The next line is the user description of the perimeter
- The following group of lines are the nodes that make up the perimeter

6.7 Print Mesh Input Data (Nodes and Elements)

Sub-menu 6, Option 7. This option prints node and element information from the original mesh of the model. The user can select to print all or some of the node and element information. This option is useful for a printed backup of the input mesh data.

The following actions are performed when the user selects this option.

- 1) The user is first prompted about what node information is to be saved.
 - The program prompts for which nodes to print out. This option allows the user to choose all the nodes or a subsection of nodes.

- The maximum number of nodes is displayed on the screen. The user is prompted for the first and last node in a series to print. To select all nodes, the user will enter 1 and the maximum number of nodes at the prompts. To select a subset, the user will answer with the node numbers he wishes to print. The program will then print out this selection. Node information is printed out as follows:

Node number, X coordinate, Y coordinate

- The program will continue to ask for first/last pairs of nodes. It will stop once the last node prompt is equal to the maximum number of nodes, or when a value of -99 is entered for either of the prompts.

2) The user is now prompted for which elements to print information on.

- The program prompts for which elements to print out. This option allows the user to choose all the elements or a subsection of elements.
- The maximum number of elements is displayed on the screen. The user is prompted for the first and last element in a series to print. To select all elements, the user will enter 1 and the maximum number of elements at the prompts. To select a subset, the user will answer with the element numbers he wishes to plot. The program then prints this selection. Element information is printed out as follows :

Element number, Node 1, Node 2, Node 3, Node 4

- The program will continue to ask for first/last pairs of elements. It will stop once the last element prompt is equal to the maximum number of elements, or when a value of -99 is entered for either of the prompts.

6.8 Print Elements for Each Sub-Region

Sub-menu 6, Option 8. This option provides a printed record of the elements that belong to each subregion. The subregions are defined by different material properties. Elements of the same material type belong to the same subregion. The program prints the elements in consecutive order, from 1 to the number of elements in the model.

The following information is printed by this selection:

- The first column contains the starting element of a series of elements that have the material property shown in the next lines.
- The next column is a description of the material property of the series of elements
- The remaining columns print the Young's modulus, Poisson's ratio and subregion number of the elements in the given series of elements.

6.9 Spare

Sub-menu 6, Option 9. This option is not available yet. It is left open here as it will be used in future versions of the program.

6.10 Return to Main Menu

Sub-menu 6, Option 10. This option returns the user to the main menu, where he may proceed with further processes in the program.

4.8 Sub-menu 7: Prepare results for plotting

Sub-menu 7 saves various information about the model in graphical forms to plot files. A listing of these plot files can be seen in Table 1. The program Quad itself does not have the facilities to plot output. The output files are therefore used with other programs to produce plotted output.

For the purposes of plotting, two programs were included along with the Quad programs. These programs were Splotcon and Quick Plot. Refer to Appendix F for information on using these programs to produce output.

7.1 Prepare a Mesh Plot

Sub-menu 7, Option 1. This option is exactly the same as the one found in Sub-menu 3, Option 2. Please refer to that section of the manual for more help.

7.2 Prepare Perimeters for Plotting

Sub-menu 7, Option 2. This selection is the same as choosing Sub-menu 3, Option 4. Refer to that section if there are any questions.

7.3 Prepare Element Results for Plotting

Sub-menu 7, Option 3. This option includes a list of 16 choices. These choices are outlined in Table 10. Displacement vectors are stored in QUAD.PV. Stresses are stored in QUAD.PS. Numerical values, such as the value of displacements, etc., are stored in QUAD.PG. All values or vectors are placed at the centre of the chosen elements. The following paragraphs provide more detail on the what output the choices provide.

Choice 0 stops the processing of element data to plot. Control of the program is returned to Sub-menu 7.

At some point the user is prompted to chose which elements to plot out and how to plot them out. For the rest of the options, it will be assumed that the user is asked to make these choices. The description of the choices listed in Table 10 will consist only of what output is sent to the various plot files. The steps involved in choosing the elements described above are as follows:

1) The user is prompted how element information is to be plotted out.

- a) The program prompts for how pen colours are to be selected. The user has four options. Option 0 will select no colour. Option 1 will allow the user to select the pen colour interactively. Option 2 will take the pen numbers defined in the material properties. Option 4 will select the colour according to the sign of the value being plotted. The normal selection is pen 2 for positive values and pen 3 for negative values. The pen number for the negative value may change, though, as the user is later prompted for the pen number to assign to this value.
- b) If option 1,2 or 3 is selected in 1a, the program prompts for which elements to display information at. This option allows the user to choose all the elements or a subsection of elements.

The maximum number of elements is displayed on the screen. The user is prompted for the first and last element in a series to send information on to the plot file. To select all elements, the user will enter 1 and the maximum number of elements at the prompts. To select a subset, the user will answer with the element numbers he wishes to plot.

The program will go to step 1c to select the colour of the pen if the user selected option 1 or 3 in 1a, then it will store the information in the appropriate plot file.

The program will continue to ask for first/last pairs of elements. It will stop once the last element prompt is equal to the maximum number of elements, or when a value of -99 is entered for either of the prompts.

- d) The program prompts the user for the plotter pen colour if he chose in 1a to select the pen colour. The user can choose pen number 1 to 4. If the user chose to not select a pen colour, or chose to use the pens defined by the material properties, this prompt is skipped.

Choice 15 will send stress and displacement vectors to the QUAD.PS and QUAD.PV files, respectively. No values are saved to the QUAD.PG file.

Choices 1 through 10 save the specified in values the QUAD.PG file. Information values are placed at the centre of the elements chosen. This options also saves the graphic vectors for stresses and displacements in the QUAD.PS and QUAD.PV files.

Choices 11 through 14 are for failure analysis.

Choice 11 deals with Hoek's rock mass failure criterion, the FOS factor of safety. This feature tests whether or not shear stress failure has occurred. This choice prompts for the following input:

- The rocks uniaxial compressive strength (in MPa)
- The rocks Hoek's M value (between 0.5 and 7.5)
- The rocks Hoek's S value (between 0.00001 and 0.5)
- The normal element choices as described above.

The user should be careful not to mix or confuse the application of Hoek's and Mohr criteria in a single run, particularly if non-linear runs are being carried out.

The output from this choice is stored in QUAD.PG. The values stored have the following meaning. For values greater than or equal to 1.0, no shear stress failure has occurred. For all other values, shear stress failure has occurred.

Choice 12 deals with Hoek's test for excessive stresses. This feature tests whether or not tensile failure has occurred. The program prompts the user for the following input:

- The rocks uniaxial compressive strength (in MPa)
- The rocks Hoek's M value (between 0.5 and 7.5)
- The rocks Hoek's S value (between 0.00001 and 0.5)
- The normal element choices as described above.

The output from this choice are stored in QUAD.PG. Again, no information is stored to the other two files. Values stored are stresses. The value calculated is the amount by which the maximum principal stress can increase before failure would occur (according to the Hoek's failure criterion). A large positive value implies that the element is not in a state of failure. Negative values would indicate that material failure has occurred in the element in question. Refer to Figures 8 and 9 and the keyword ELTP in Appendix B for further explanation.

Choice 13 deals with an extension strain failure test. Values are store in QUAD.PG. The values returned are strains.

Choice 14 is a Mohr Coulomb excess stress failure test. This choice tests for tensile failure as well. Note, for this test, the Mohr curve is not used, but a straight line approximation to the curve. Refer to Figures 10 and 11 for more information. The user is only prompted for element information as described above.

Output is stored once more in QUAD.PG. The values stored are stresses, and have the same meanings as described in the Hoek's excessive stresses failure test. Refer to keyword ELTP in Appendix B for more information.

7.4 Prepare Nodal Results for Plotting

Sub-menu 7, Option 4. This option plots nodal results. This option includes a list of 9 choices. These choices are outlined in Table 11. Displacement or force vectors are stored in QUAD.PV. Numerical values, such as the value of displacements, etc., are stored in QUAD.PN. All values or vectors are placed at the position of the chosen nodes. The following paragraphs provide more detail on the what output the choices provide.

Choice 0 stops the processing of nodal information, and returns the user to Sub-menu 7.

For each of the choices 1 to 8, the user will be prompted for information on how data is be plotted at the nodes. In each case, the values of the choice will be stored in QUAD.PN, and the vector of displacement or force will be save to QUAD.PV. The following paragraph describes how to select the required nodes.

- 1) The user is prompted about which nodes are to have information plotted at.

- a) The program prompts the user for the plotter pen colour to use in plotting node information. The user has two options. Option 0 will select no pen colour. Option 1 will let the user select the pen colour later in the program. Select Option 0 if node information is not to be plotted.
- b) The program then prompts for how information is to be plotted at the selected nodes. There are three options. Option 0 will plot nothing at the nodes. Option 1 will plot the desired value at the nodes. Option 2 will plot an X at the nodes.
- c) If option 1 or 2 is selected in 1b, the program prompts for which nodes to display information at. This option allows the user to choose all the nodes or a subsection of nodes.

The maximum number of nodes is displayed on the screen. The user is prompted for the first and last node in a series to send to the plot file.

To select all nodes, the user will enter 1 and the maximum number of nodes at the prompts. To select a subset, the user will answer with the node numbers he wishes to plot.

The program will go to step 1d to select the colour of the pen if the user chose to select the colour, then it will store the vector in QUAD.PV, and the value for the chosen option in Table 11 in QUAD.PN.

The program will continue to ask for first/last pairs of nodes. It will stop once the last node prompt is equal to the maximum number of nodes, or when a value of -99 is entered for either of the prompts.

- d) The program prompts the user for the plotter pen colour if he chose in 1a to select the pen colour. The user can choose pen number 1 to 4. If the user chose to not select a pen colour, this prompt is skipped.

One small note. If the user chose to have no pen colour, and to plot nothing at the nodes, the user will not be prompted for a series of nodes, and program control will return to Sub-menu 7.

7.5 Prepare a Deformed Mesh for Plotting

Sub-menu 7, Option 5. The deformed mesh is what the input mesh looks like if all displacements calculated by the program are applied to the nodes. The mesh is stored in the plot file QUAD.PD. This option runs very similar to the plotting of the input mesh, as described in Sub-menu 3, Option 2.

The way this option runs is as follows:

- The user is prompted to enter a scaling factor for displacements. This can be useful in exaggerating actual movements calculated by the program. The actual value entered will depend on the model being used, though it is always greater than zero (0).
- The program then prompts for node and element information as in Sub-menu 3, Option 2.
- Once all prompts are answered, the deformed mesh is stored in QUAD.PD. Node and element information is store in QUAD.PN and QUAD.PE, respectively.

7.6 Spare

Sub-menu 7, Option 6. This selection is not in use yet. It is reserved for future versions of the Quad program.

7.7 Return to Main Menu

Sub-menu 7, Option 7. This returns the user to the main menu. Once there, the user can continue on with the program.

4.9 Sub-menu 8: Digitizer utilities

Sub-menu 8 contains several routines for inputting data to the Quad program using a digitizer. Information on nodes, elements, boundary condition and perimeters can be entered with a digitizer. Entering data in this manner can sometimes save the user hours in typing data into computer files for use in the program.

8.1 Set Up Digitizer and Plan Scales

Sub-menu 8, Option 1.

8.2 Digitize Nodal Coordinates

Sub-menu 8, Option 2.

8.3 Digitize the Nodes for Selected Elements

Sub-menu 8, Option 3.

8.4 Digitize Nodal Boundary Conditions

Sub-menu 8, Option 4.

8.5 Digitize Nodes Defining a Contour

Sub-menu 8, Option 5. Not yet in use.

8.6 Digitize Outlines for Plotting

Sub-menu 8, Option 6.

8.7 Display/Check Node, Elements, and Boundary Conditions

Sub-menu 8, Option 7.

8.8 Return to Main Menu

Sub-menu 8, Option 8. This option returns the user to the main menu, where he may continue on with the program.

4.10 Sub-menu 9: Documentation and help

Sub-menu 9 provide on line documentation and help in running Quad. Currently, only documentation on current keywords is available to the user. Future version may include more extensive on line help for the user.

9.1 List Available Keywords for Data File Preparation

Sub-menu 9, Option 1. Selecting this option will display to the screen information on currently available keywords and a brief description of their use.

9.2 Spare

Sub-menu 9, Option 2. This option is not yet available to the user. It will be used in future versions of the program for more documentation or help.

9.3 Return to Main Menu

Sub-menu 9, Option 3. Returns the user to the main menu for more processing.

4.11 Sub-menu 10 advanced utilities

Sub-menu 10 offers advanced utilities to users with a good knowledge of how Quad works. These range from viewing various system arrays, to viewing and modify the message file used by Quad.

10.1 Display/Check Selected Nodes/Elements

Sub-menu 10, Option 1. This option will display nodes and elements to the screen. It will also perform rudimentary checking on element, making sure they are defined correctly. When the user is asked to select a range of elements or nodes to look at, the general format of entering the first and last element or node is followed.

Once this option is selected, the screen displays four (4) choices for the user. Option 1 is to display node coordinates. Option 2 is to display elements and their nodes. This option also performs the element checking. Option 3 displays the boundary condition at nodes that have conditions defined. The final option is option 0, which will stop the cycle of choosing displaying information with the other options.

After choosing option 1, the user is prompted for a range of nodes to display information on. The user will enter the range he wishes to view, of -99 for either of the prompts to get out of this option. If an range of nodes was selected, the following information is printed about each:

- Node number, X coordinate, Y coordinate

Program control then returns to the previous screen with the four options.

After choosing option 2, the program prompts for a range of elements to display information on. If a range of elements is given, the following information is displayed for each element:

- Element number, Node 1, Node 2, Node 3, Node 4

This option also performs a check of elements, to make sure they are defined correctly. If at all possible, the elements are corrected by the program. When a problem is encountered, a message flag is placed by the element and its node. This flag contains a number referring to a list of errors and possible ways of correcting them. Refer to Table 12 for this listing.

Choosing option 3 will display all nodes with boundary conditions defined. The format for the output is:

- The node number and the boundary condition code.

Once option 0 is chosen, the program enters another section of this Sub-menu 10 option. This section allows the user to change the number of nodes, elements, and boundary conditions for the current model.

To change any of these values, the user would enter a new number. To leave the values as they are, the user must enter a 0 at the prompt.

Once all the prompts have been answered, the program saves the changes (if any), and returns to Sub-menu 10.

10.2 Display Element Information

Sub-menu 10, Option 2. This allows the user to display information about elements to the screen. It is a compact way of getting all major information about elements in one place.

The program displays the number of elements defined in the current model. The user is then prompted for a range of elements to print information on. The user enters the first and last elements in a range he wishes to see. To view the all elements, enter 1 and the number of elements in the model for the first and last elements in the range. To display a subsection, enter the first and last element numbers in the subsection.

The program will then display information on the selected elements. The form of the output will be given in a moment.

The program will then loop back, asking for another range of elements to look at. This looping will stop when the value for the last element in the series is the number of elements in the model, or when the user enters a value of -99 for either prompt.

The following information is displayed for each element in the series chosen:

- NOTE: All information is store in the QUAD.ELT database file. Refer to Table 3 for a listing of the contents of the file.

- The first line states the element number, X and Y coordinate of the centre of the element, and the area of the element. These values are as for the element before an analysis was done.
- The second line displays the values in the IELP array. Refer to Table 3 for a description of each of the array positions. Position 1 through 14 are displayed.
- The next section of lines displays information on stresses, strains, and displacement. These values are given at each of the nodes that make up the element.
- The first section of lines is for the stresses. This section is made of 3 lines, one for Total, Primitive, and Incremental stresses. These values are stored in the arrays TSTRES, PSTRES, and ESTRES, respectively.
- The second section is one line of strain information. This line prints out the total strains stored in the ESTR array.
- The final section of lines is for displacements. This section is made of 4 line, total U and V displacements, and incremental U and V displacements. Information is stored in the UTOT, VTOT, UN, and VN arrays, respectively.

10.3 Display Arrays in File QUAD.ARR

Sub-menu 10, Option 3. This option allows the user to view all arrays that are in the QUAD.ARR file. A listing of the arrays in the file is found in Table 2. In this selection, the user has 20 arrays to choose from to look at. To return back to Sub-menu 10, the user will enter a value of 0 or -99.

For all of the options, the following is the format of actions performed:

- 1) The user is asked if he wishes to skip over zero values in the display. The user will answer y or Y for yes, and N or n for no.
- 2) The program then prompts for a series of nodes or elements to display information about. The standard first/last arrangement of input is used. The user will enter -99 if he does not wish to proceed further with this option.
- 3) Once a range is set, the program displays the appropriate information to the screen. Refer to Table 2 for information on what is being displayed.
- 4) The program then displays a summary of information displayed in 3 above. It displays the sum of information over the number of nodes/elements in the selected range. It then prints the average value of the displayed values over this range.
- 5) The program then loops back to step 2, allowing the user to display more information on this option.

10.4 Display File Status and Switch Registers

Sub-menu 10, Option 4. This option will display on the screen the status of the file, integer and real switches registers. These values are stored in the arrays IFSTAT, ISSW, and SSW.

The output produced by this option is as follows.

- The first section of lines shown are for the integer switches stored in the array ISSW. There are 20 switches, and the values are displayed beneath the switch number.
- The next section of lines contain the information for the real switch stored in the SSW array. There are 10 switches, and value are shown beneath the switch number.
- The array IFSTAT is shown in the next section of lines. There are 20 file channels that can be open at one time, and below each of the channel numbers is the status of the channel.
- The program then displays information about the current model to the screen. The format of this display is that shown in Table 8.

10.5 Load in a New Message File

Sub-menu 10, Option 5. This option allows advanced users to load in new message files when they become available. This option requires the use of a password. This way only authorized personnel may load a new message file.

The user is prompted for the password. If the correct password is given, the program prompts the user for the name of the new message file to load.

10.6 Display or Modify Messages

Sub-menu 10, Option 6. This option allows advanced user to view and change the existing message file. Again, only authorized users with the correct password may make changes to the file.

The user is first prompted for the password. If the correct one is given, the user will proceed with this option.

The actions performed by this option are as follows:

- 1) The user is prompted for the line number in the message file to display or modify. The user will enter the number of the line, or -99 to stop this selection and return to Sub-menu 10.
- 2) If a line was selected, it is printed to the screen.
- 3) The program then prompts for a new message line to replace the current one. In this way the user may modify the existing message file. To modify the current value, just input the string that is to replace the old message. If the line is to be left alone, enter -99. The program will then loop back to step 1 to display/modify more message file lines.

10.7 Print Out Messages

Sub-menu 10, Option 7. This allows advanced users to produce hard copy of any changes made to the existing message file, or to print out the contents of any recently loaded message files. This option does not require a password, but currently only the line number of the messages are printed out.

10.8 Return to Main Menu

Sub-menu 10, Option 8. This option will return the user back to the main menu. Once there, the user can continue on using the program as he wishes.



LIST OF TABLES

Table 1: Database structure of QUAD	34
Table 2: Contents of QUAD.ARR file	35
Table 3: Contents of QUAD.ELT file	36
Table 4: Contents of QUAD.MAT file	37
Table 5: Material type codes in array MTYP	37
Table 6: Contents of QUAD.STF file	38
Table 7: Contents of QUAD.FIL file	38
Table 8: Sub-menu 3, Option 1 output	39
Table 9: Non-linear material types and output parameters	39
Table 10: Choices for values to plot at elements	40
Table 11: Choices for values to plot at nodes	40
Table 12: Element numbering checker	41

Table 1: Database Structure of Quad

Channel	Filename	Type	Description
21	QUAD.COM	P	Main common block
22	QUAD.ELT	P	Element geometry file
23	QUAD.MAT	P	Material properties file
24	QUAD.ARR	P	Big arrays file
25	QUAD.STF	P	Global stiffness matrix file
26	QUAD.PER	P	Perimeters file
27	QUAD.EST	P	Element stiffness file
28	QUAD.MUL	P	Multiple step control file (not used yet)
29	QUAD.NOD	P	Nodal stresses/strain (not used yet)
30	DIGITIZER	I	Channel for reading from digitizer
31	QUAD.PV	O	Plot file for vectors
32	QUAD.PG	O	Plot file for general items
33	QUAD.PS	O	Plot file for stresses
34	QUAD.PI	O	Plot file for integer numbers
35	QUAD.PN	O	Plot file for node numbers
36	QUAD.PE	O	Plot file for element numbers
37	QUAD.PM	O	Plot file for mesh
38	QUAD.PD	O	Plot file for deformed mesh
39	QUAD.PP	O	Plot file for perimeters
50	QUAD.MES	P	Message file

LEGEND

Type

I=Input file

O=Output file

P=Program Database files

Table 2: Contents of QUADARR File

Number	Array	Size	Start	Dimensions	Description
1	X	2	1	1536	X-coordinate
2	Y	2	3	1536	Y-coordinate
3	U	2	5	1536	X-displacements
4	V	2	7	1536	Y-displacements
5	BCX	2	9	1536	X-boundary
6	BCY	2	11	1536	Y-boundary
7	UTOTX	2	13	1536	X total displacement
8	UTOTY	2	15	1536	Y total displacement
9	IBC	1	17	1536	Nodal b.c. code
10	MATEL	1	19	1536	Material subregion
11	NODEL	4	21	6144	Nodes numbers/elts
12	ID	2	29	3072	Matrix profile index
13	JDIAG	2	33	3072	Matrix profile index
14	ISORT	1	37	1536	Sort array for nodes
15	FX	2	39	1536	Incremental boundary forces
16	FY	2	41	1536	Incremental boundary forces
17	IDUMP	1	43	1536	Disk dump pointer
18	FXTOT	2	45	1536	Total X force
19	FYTOT	2	47	1536	Total Y force
20	IGRAV	1	49	1536	Gravity on/off

Table 3: Contents of QUAD.ELT file

Item	Size	Address	Description
XELC	1	1	X coordinate element centre
YLEC	1	2	Y coordinate element centre
ANGL1	1	3	Angle of anisotropy
ANGL2	1	4	Angle of rotation for stresses
XEN	4	5-8	X nodal coordinates
YEN	4	9-12	Y nodal coordinates
UN	4	13-16	X nodal non-linear displacement
VN	4	17-20	Y nodal non-linear displacement
AEL	1	21	Area of element
D	16	31-46	D matrix
PORE	1	22	Not used yet
PSTRES	4	47-50	Primitive stresses
TSTRES	4	51-54	Total stresses
THIK	1	23	Not used yet
ESTRES	4	55-58	Effective stress (not used yet)
ESTR	4	59-62	Total element strain
UTOT	4	63-66	Total X displacement (non-linear)
VTOT	4	67-70	Total Y displacement (non-linear)
IELP(1)	1		Status (0 = lin, ..., 999 = dead)
IELP(2)	1		Library code
IELP(3)	1		Current non-linear status
IELP(4)	1		Material subregion number
IELP(5)	1		Degrees of freedom per node
IELP(6)	1		Number of nodes per element
IELP(7)	1		Integration accuracy
IELP(8)	1		Element number
IELP(9)	1		Element status code
IELP(10)	1		Print / No print flag
IELP(11-14)	4		Node numbers
IELP(15)	1		Spare
IELP(16)	5		Spare

Table 4: Contents for QUAD.MAT file

Item	Size	Description
E1	1	Young's modulus
V1	1	Poisson's ratio
E2	1	Anisotropic Young's modulus
G2	1	Anisotropic shear modulus
V2	1	Anisotropic Poisson's ratio
ANISO	1	Anisotropic angle (default)
DEN	1	Density
DESMAT	16	Description of subregion
MPEN	1	Pen number for plotting
MTYP	1	Material type (eg Mohr Coulomb)
ISO	1	Isotropic (0) / Anisotropic (1) cod
e		
MSTAT	1	Material status code (not used yet
)		
MSYS	1	Material status code (not used yet
)		
PARM	10	Up to ten (10) material properties
SPARE	1	Spare

Table 5: Material Type Codes in Array MTYP

Code value	Description
0	Linear material
1	Non tension material
2	Mohr Coulomb (associated flow rule)
3	Mohr Coulomb (non-associated flow rule)
4	Special air element for multiple step analysis
5	Air element with total closure restrictions
6	Hoek's failure criterion (not ready yet)
7	Non-linear backfill (Quadratic)
8	Non-linear backfill (Cubic)
9	Spare
10	Joint material (one set) (also 20,30,40,50)
12	Joint matrial (two sets) (also 13,23,24,etc)
100	Infinite elements
200	Anchor elements
500	Descrete joint elements (not used yet)
999	Dead elements

Table 6:Contents of QUAD.STF file

Item	Size	Address	Description
COEF	64	EST(1)	Coefficients for element stiffness
EST(2)	1		Status (1 = okay, 0 = dead)

Table 7: Contents of QUAD.FIL file

Line #	Filename	Description
1	QUAD.COM	Common block containing general system information
2	QUAD.ELT	Element geometry
3	QUAD.MAT	Material properties
4	QUAD.ARR	Nodal and elemental arrays
5	QUAD.STF	Global stiffness arrays
6	QUAD.PER	Perimeters
7	QUAD.ELT	Element stiffness
8	QUAD.MUL	Information for multiple step analysis (not used yet)
9	QUAD.NOD	Nodal stress / strain (not used yet)
10	USER	Input data file name
11	QUAD.MES	Message file containing screen prompts
12	TEMP.LST	Printout destination
13	QUAD.PV	Plot file for vectors
14	QUAD.PG	Plot file for general items
15	QUAD.PS	Plot file for stresses
16	QUAD.PI	Plot file for integers
17	QUAD.PN	Plot file for nodes numbers
18	QUAD.PE	Plot file for elements numbers
19	QUAD.PM	Plot file for mesh
20	QUAD.PD	Plot file for deformed mesh
21	QUAD.PP	Plot file for perimeters

Table 8: Sub-menu 3, Option Output

NUMBER OF NODES	121
NUMBER OF ELEMENTS	100
NUMBER OF MATERIAL TYPES	4
PLAIN STRESS(1) PLAIN STRAIN(2) AXI-SYMMETRIC(3)	2
NDIMD --- ARRAY DIMENSION --- 3 FOR PLAIN OR 4 FOR AXI-SYMMETRIC	3
Number of perimeters/contours (defined by nodes)	2
CONSTANT PRIMITIVE STRESS IN X-DIRECTION	0.000
CONSTANT PRIMITIVE STRESS IN Y-DIRECTION	0.000
CONSTANT PRIMITIVE SHEAR STRESS	0.000
DEPTH VARIATION OF PRIMITIVE STRESS IN X-DIRECTION	0.000
DEPTH VARIATION OF PRIMITIVE STRESS IN Y-DIRECTION	0.000
DEPTH VARIATION OF PRIMITIVE SHEAR STRESS	0.000
A linear run has been specified	
--- or ---	
A non linear run has been specified	
Number of Non-linear iterations	60
Acceleration factor for Non-linear iterations	1.300
Convergence limit for Non-linear iterations (Unit of stress)	0.010

Table 9: Non-linear Material Types and Output Parameters

Type Code	Description	Parameters Outputed
1	No tension material	Tensile strength
2	Mohr Coulomb material	Tensile strength, cohesion and angle of friction of joint set
3	Non-ass Mohr Coulomb	Tensile strength, cohesion, angle of friction, and dilatancy factor of joint set
4	Special air elements	nothing
5	Total closure elements	nothing
6	Hoek's failure criterion	nothing
7	Backfill (Quadratic)	Coefficients of quadratic equation, A, B and C
8	Backfill (Cubic)	Coefficients of cubic equation, A, B and C
10	Jointed material	Tensile strength, cohesion, angle of friction, and dilatancy factor of joint set
12	Jointed material	Tensile strength, cohesion, angle of friction, and dilatancy factor of joint set

Table 10: Choices for Values to Plot at Elements
(sub-menu7, Option 3)

Choice #	Description of choice
1	For horizontal displacements
2	For vertical displacements
3	For Max stresses
4	For Min stresses
5	For Max shear stresses
6	For vertical stresses
7	For horizontal stresses
8	For maximum strains
9	For minimum strains
10	For extension strains
11	For Hoek's rock mass failure criterion (FOS)
12	For Hoek's excess stresses
13	For volumetric strains
14	For Mohr Coulomb excess stress
15	For stresses and displacement vectors only

Table 11: Choices for Values to Plot at Nodes
(Sub-menu 7, Option 4)

Choice #	Description of choice
1	For horizontal total displacements
2	For vertical total displacements
3	For horizontal incremental displacements
4	For vertical incremental displacements
5	For total horizontal forces
6	For total vertical forces
7	For incremental horizontal forces
8	For incremental vertical forces

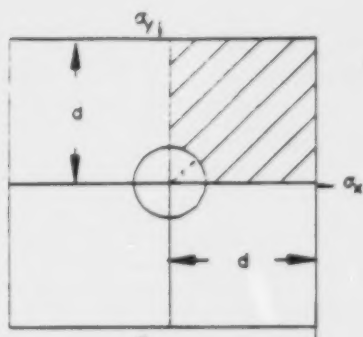
Table 12: Element Numbering Checker
(Sub-menu 10, Option 1)

Type	Element	Description of error	Fixable by Quad
1	44,44,55,66	Triangle element with bad order	Yes
2	33,44,44,66	Triangle element with bad order	Yes
3	33,44,55,33	Triangle element with bad order	Yes
4	44,55,44,66	Bad element	No
5	33,44,55,44	Bad element	No
6	44,55,0,66	Illegal zero node	Possible*
7	77,66,55,44	Reverse ordering (clockwise)	Yes
8	77,66,55,55	Reverse ordering for a triangle element	Yes

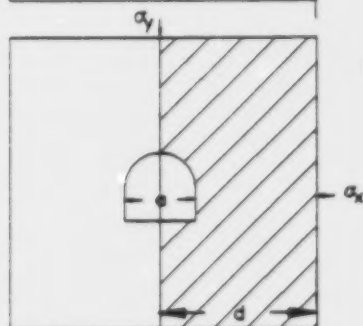
*Note: element is fixable if the node is the fourth node of the element, and no other nodes are zero.

LIST OF FIGURES

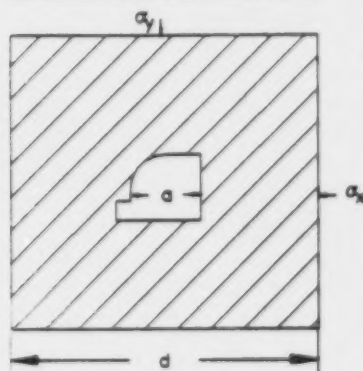
Figure 1: Illustration of Planes of Symmetry	42
Figure 2: Illustration of Planes of Symmetry with Geological Discontinuities	43
Figure 3: Example of a Mesh for a Circular Tunnel (Two symmetry)	44
Figure 4: Outer Mesh for Circular Tunnel	45
Figure 5: Non-linear Run, Original Mesh	46
Figure 6: Non-linear Run, Elements	47
Figure 7: Non-linear Run, Nodes	48
Figure 8: Hoek's Excess Stresses (Compressive Stress Value Returned)	49
Figure 9: Hoek's Excess Stresses (Tensile Stress Value Returned)	50
Figure 10: Mohr Coulomb Excess Stresses (Compressive Stress Value Returned)	51
Figure 11: Mohr Coulomb Excess Stresses (Tensile Stress Value Returned)	52



- a. Two planes of symmetry only one quadrant needs to be modelled.
 $d \geq 10r$ displacement on planes of symmetry to be specified as indicated.

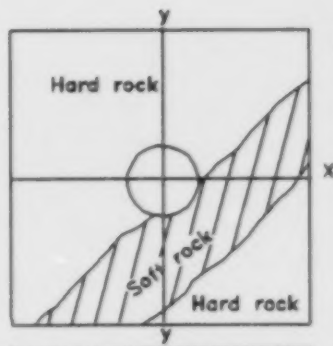


- b. One plane of symmetry only one half needs to be modelled.
 $d \geq 10a$ displacement on plane symmetry to be specified as indicated

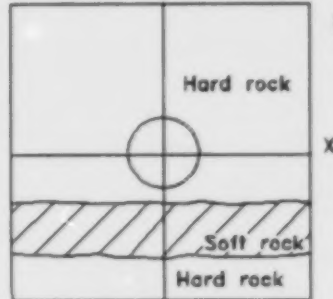


- c. No planes symmetry model completely
 $d \geq 10a$

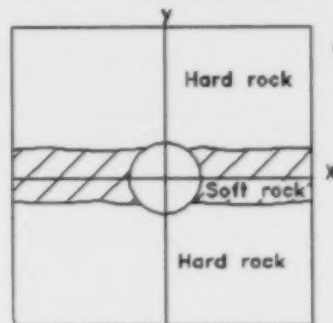
Figure 1: Illustration of Planes of Symmetry



a. No planes of symmetry complete structure must be modelled.



b. Y-Y plane is a plane symmetry.
Only one half need to be modelled.



c. Both X-X and Y-Y are planes of symmetry
only one quadrant needs to be modelled

Figure 2: Illustration of Planes of Symmetry with geological discontinuities

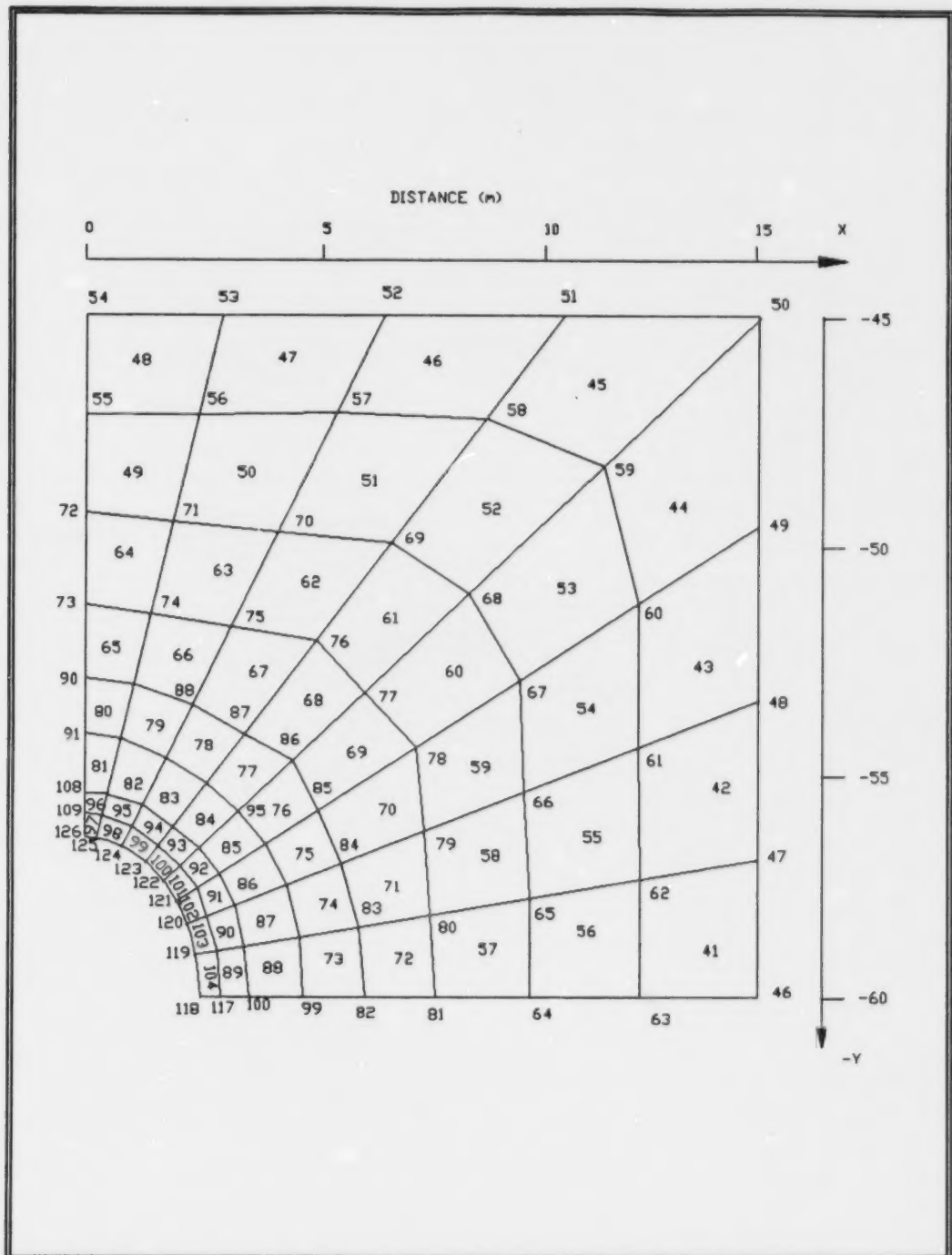


Figure 3: Example of a Mesh for a Circular Tunnel (Two Planes of Symmetry - See the other portion in fig. 4)

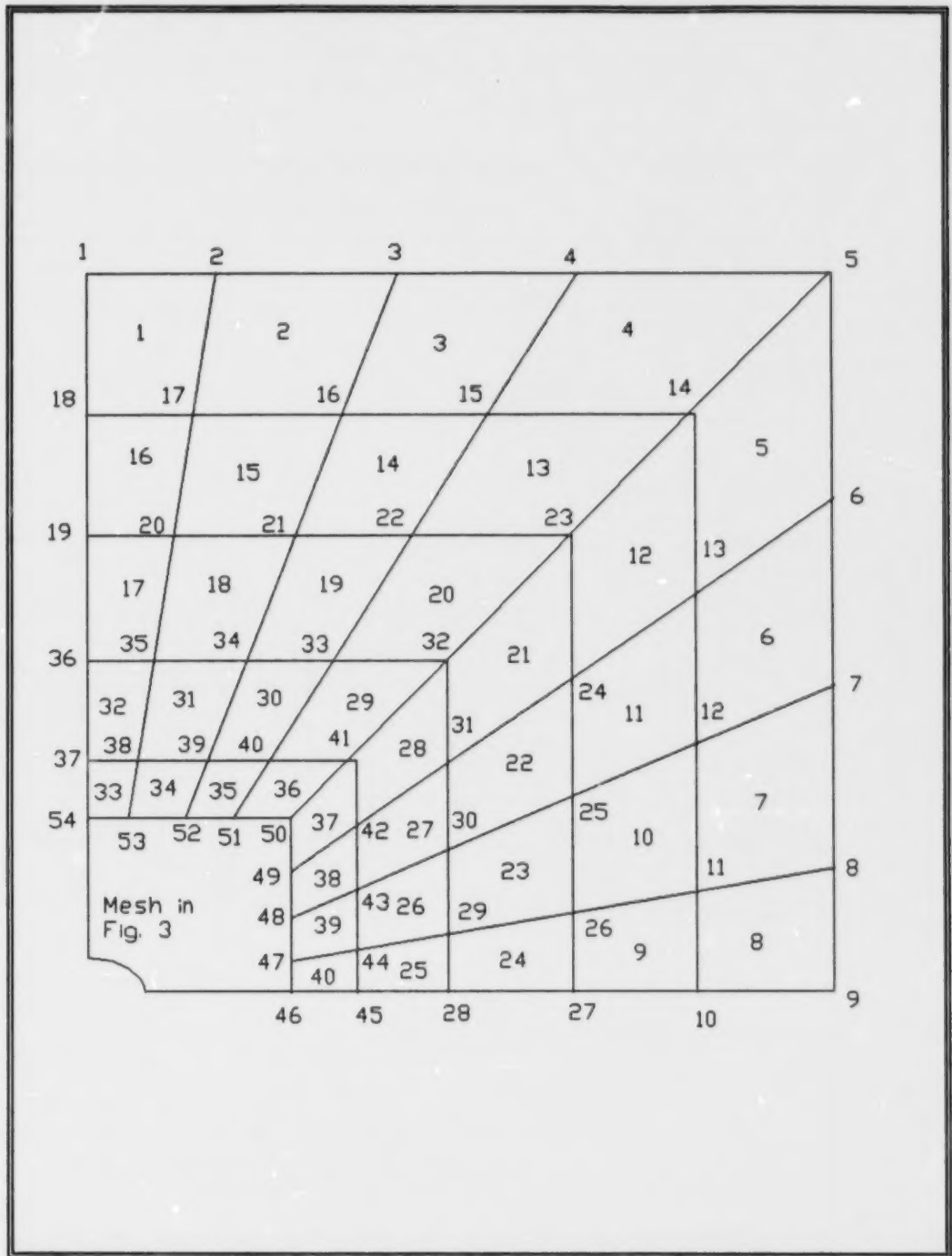


Figure 4: Outer Mesh for Circular Tunnel (for Inner Mesh See fig. 3)

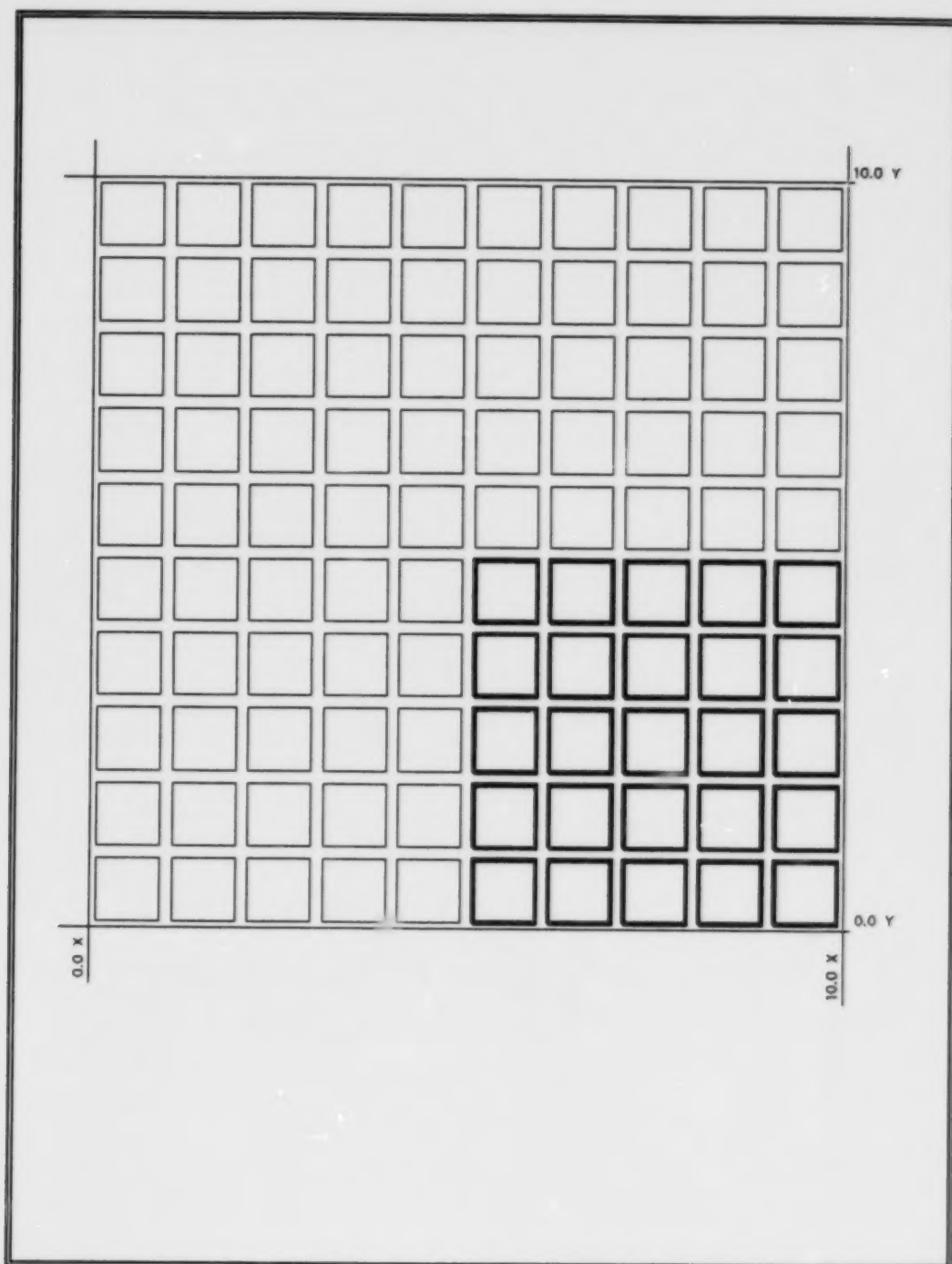


Figure 5: Non-linear Run, Original Mesh

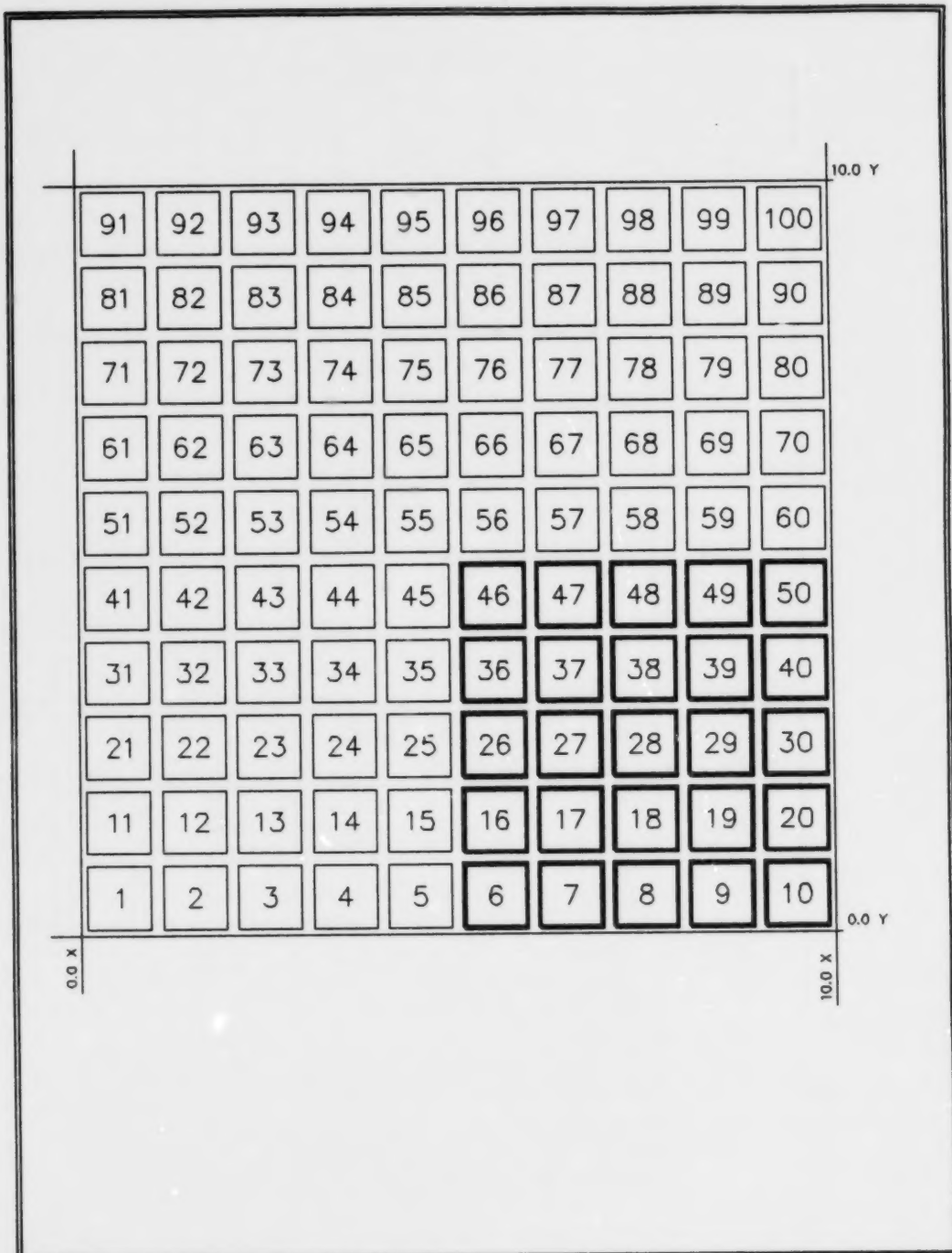


Figure 6: Non-linear Run, Elements

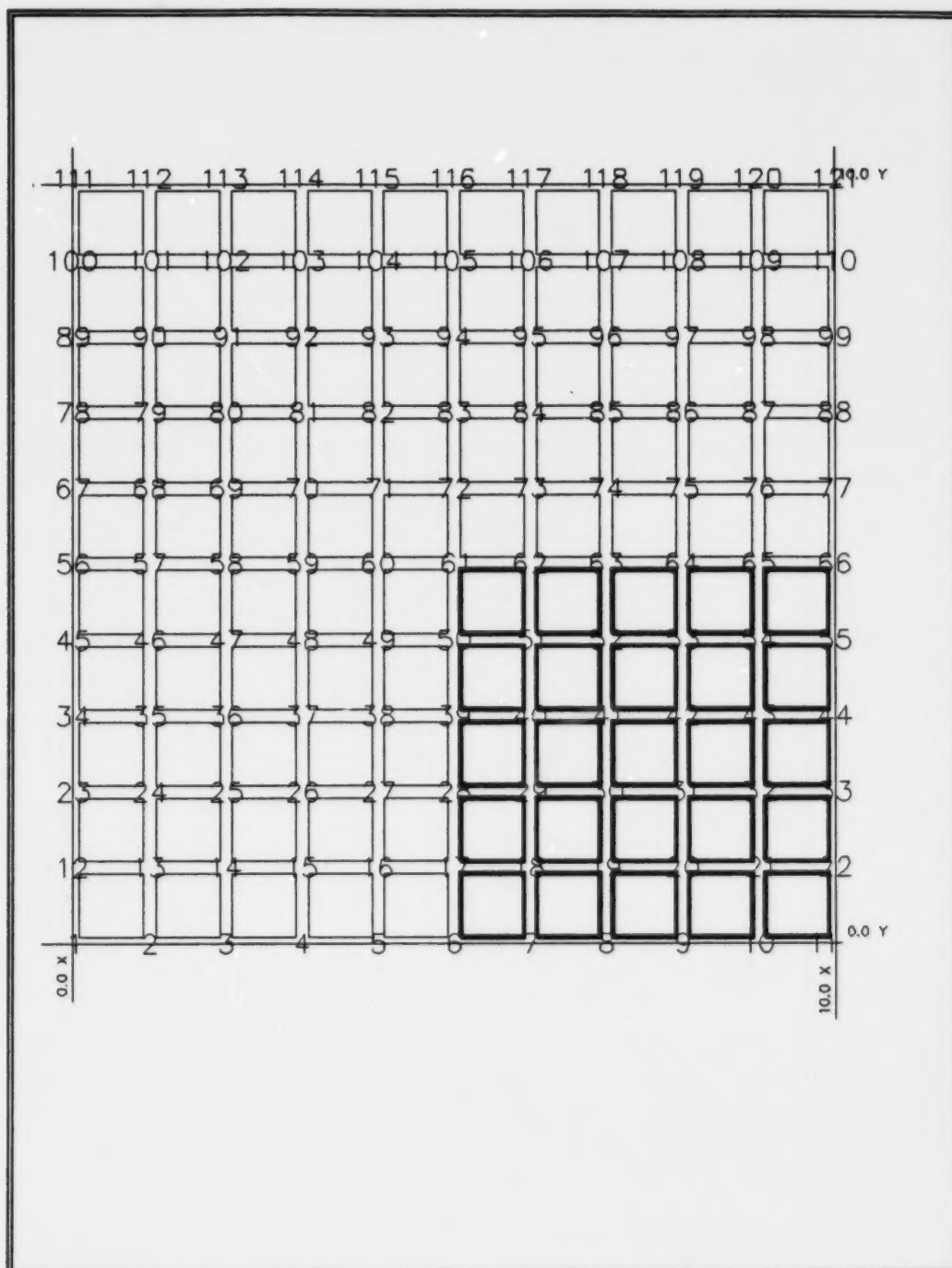
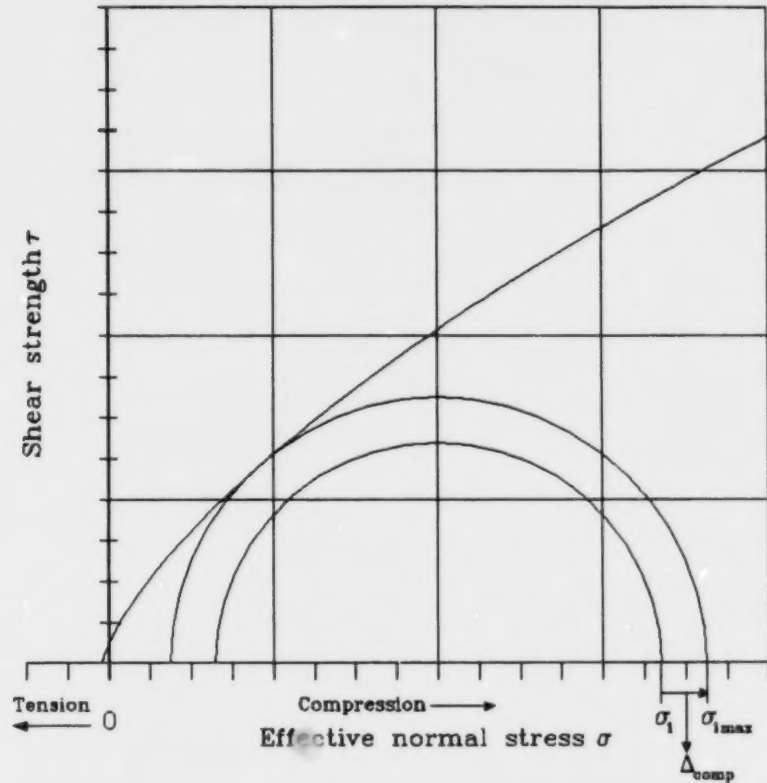


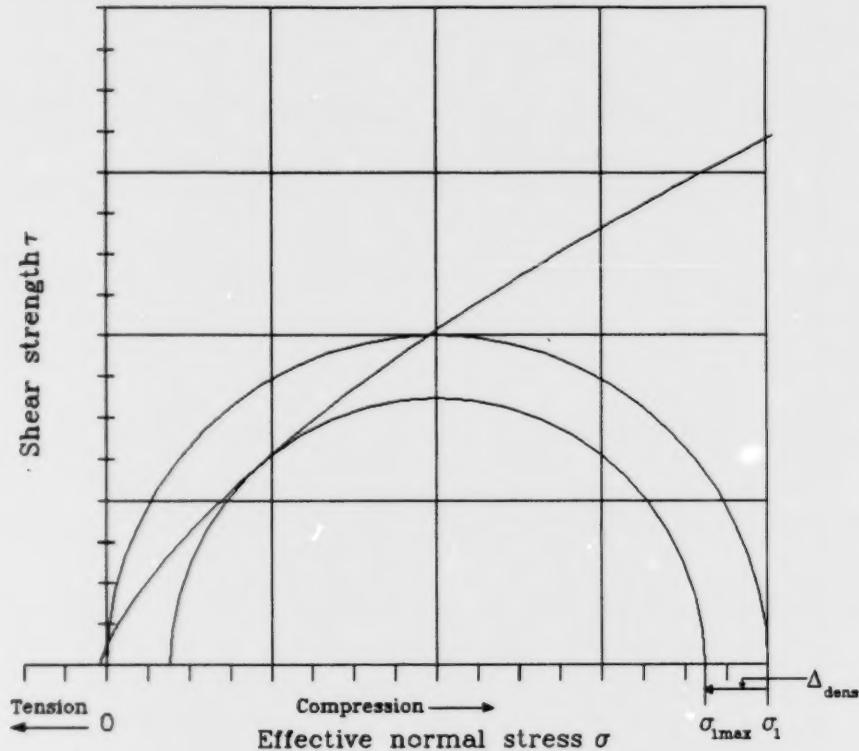
Figure 7: Non-linear Run, Nodes



NOTES:

- 1) σ_1 is the value of the largest principal stress calculated by Quad.
- 2) σ_{imax} is the value of the largest principal stress such that the circle it defines still remains under the Mohr curve.
- 3) Δ_{comp} is the value returned by Hoek's Excess Stress analysis in Quad. It is the difference between the above two stresses.
- 4) As we can add more compressive stress and still remain under the Mohr curve, no tensile stress failure has occurred.

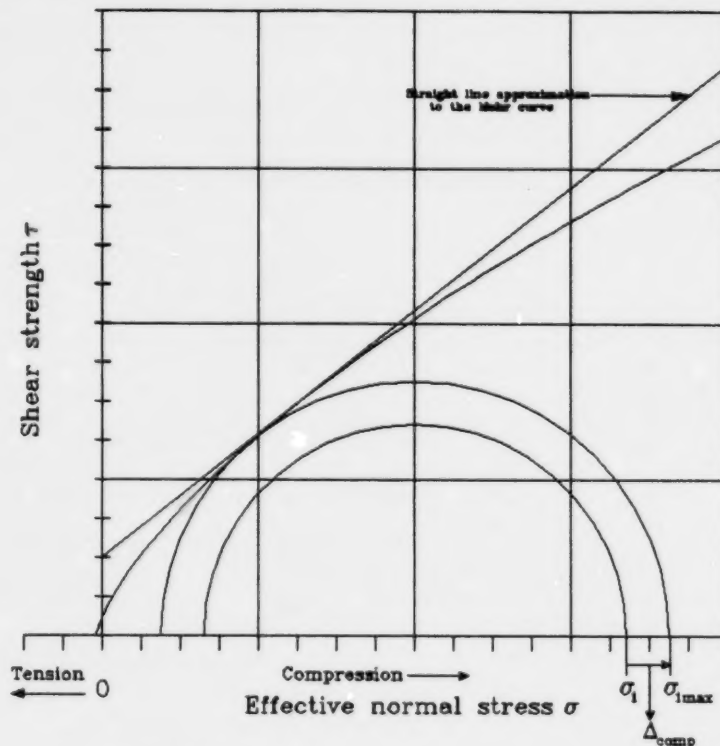
Figure 8: Hoek's Excess Stresses (Compressive Stress Value Returned)



NOTES:

- 1) σ_1 is the value of the largest principal stress calculated by Quad.
- 2) σ_{1max} is the value of the largest principal stress such that the circle it defines still remains under the Mohr curve.
- 3) Δ_{dens} is the value returned by Hoek's Excess Stress analysis in Quad. It is the difference between the above two stresses.
- 4) As we had to add more tensile stress to remain under the Mohr curve, tensile failure has occurred.

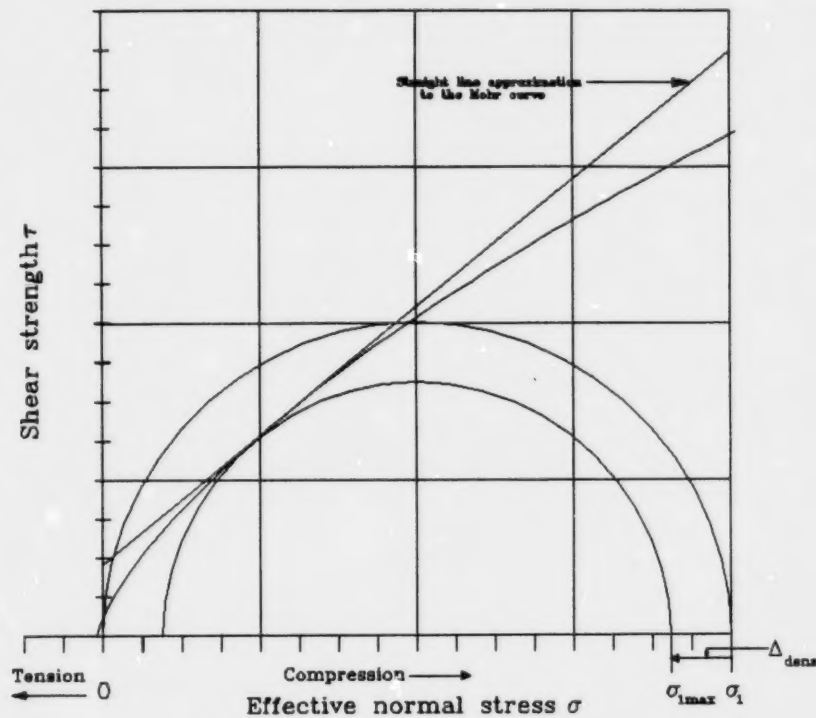
Figure 9: Hoek's Excess Stresses (Tensile Stress Value Returned)



NOTES:

- 1) σ_1 is the value of the largest principal stress calculated by Quad.
- 2) σ_{1max} is the value of the largest principal stress such that the circle it defines still remains under the Mohr curve.
- 3) Δ_{comp} is the value returned by Hoek's Excess Stress analysis in Quad. It is the difference between the above two stresses.
- 4) As we can add more compressive stress and still remain under the approximation line, no tensile stress failure has occurred.
- 5) The analysis done here uses the straight line approximation to the Mohr curve as the curve to remain under. This is fine for values around which the two curves are the same, but the results at the two ends (large and small stresses) are less accurate and may not catch failure even if they have occurred.

Figure 10: Mohr Coulomb Excess Stresses (Compressive Stress Value Returned)



NOTES:

- 1) σ_1 is the value of the largest principal stress calculated by Quad.
- 2) σ_{1max} is the value of the largest principal stress such that the circle it defines still remains under the approximation line.
- 3) Δ_{dens} is the value returned by Hoek's Excess Stress analysis in Quad. It is the difference between the above two stresses.
- 4) As we had to add more tensile stress to remain under the approximation line, tensile failure has occurred.
- 5) The analysis done here uses the straight line approximation to the Mohr curve as the curve to remain under. This is fine for values around which the two curves are the same, but the results at the two ends (large and small stresses) are less accurate and may not catch failure even if they have occurred.

Figure 11: Mohr Coulomb Excess Stresses (Tensile Stress Value Returned)

LIST OF APPENDICES

Appendix A: QUAD MESSAGE FILE

A1 - A13

Appendix B: QUAD KEYWORDS

B1 - B84

Appendix C: QUAD EXAMPLES

C1 - C33

APPENDIX A

QUAD MESSAGE FILE

A1 TO A13

MESSAGE FILE TEXT

QUAD MESSAGE FILE

.....
QUAD --- 2 D FINITE ELEMENT PACKAGE --- VERSION 4.0 --- JAN 1989

WRITTEN BY : J.A.C.DIERING
OF
STEFFEN ROBERTSON AND KIRSTEN
.....

GEMCOM or its holding company Steffen Robertson and Kirsten are not liable for any damages of any nature (whether direct or consequential) resulting from the use (or misuse) of this program.

Enter password code
THE NEXT LINE IS DELIBERATELY KEPT BLANK

ERROR MESSAGE REPORTED FROM ROUTINE QUIT
ENTER Y (YES) OR N (NO) (Check that caps lock is on)
HANG ON A SEC
ARE YOU SURE ??
THIS OPTION MAY NOT BE USED YET
OPTION COMPLETED SUCCESSFULLY
NEW VALUE ?
DOES NOT EXIST --- TRY AGAIN ---
Description for this run :
DESCRIPTION (MAX 14 CHARACTERS)
More ??? (Y/N)
RESPONSES TO BE ECHOED TO PRINTER (Y/N)
DUMMY PROMPT
ENTER START MESSAGE NUMBER
ENTER STOP MESSAGE NUMBER
ENTER NUMBER OF MESSAGES
ENTER MESSAGE NUMBER (OR -99 TO END)
ANOTHER RUN (Y/N)
Pen number (1-4)
Maximum number of equations allowed is
Maximum allowed bandwidth for nodes is
Maximum ...

ALREADY EXISTS --- TRY AGAIN ---
DOES NOT EXIST --- TRY AGAIN ---
Record number
(S) for screen or (P) for printer
Enter name of file
NUMBER
(E)dit (C)reate (V)iew (P)rint (S)ummary (M)enu or (H)elp
EDIT MODE
CREATE MODE ---- FOR NEW RECORDS

VIEW MODE

(F) TO FILE OR (Q) TO QUIT ---- EG Q
PRINTOUT BEING WRITTEN TO FILE 'TEMP.LIST'
ALL OUTPUT MAY BE PRINTED WHEN YOU SIGN OFF
DESCRIPTION OF PROBLEM

New Run

MESSAGE NUMBER

ENTER NEW MESSAGE (OR -99 TO SKIP)

YOU ARE ABOUT TO INITIALIZE ENTIRE DATA BASE AND ALL DATA

Do you wish to continue (Y/N)

Number of nodes

Number of elements

Number of different material types

Number of boundary condition nodes

Number of Non-linear iterations

Number of steps for a multi step analysis

Number of equations to be solved

Number of perimeters/contours (defined by nodes)

Number of header lines in data file

Number of nodes in this contour

Number of joint sets

Number of nodes for this element

Number of decimal places for coordinates (0,1,2 or 4)

First material number of a sequence (or -99 to end)

Last material number of a sequence

First node number of a sequence (or -99 to end)

Last node number of a sequence

First element number of a sequence (or -99 to end)

Last element number of a sequence

Node number

Element number

Material subregion number

Equation number

Contour number

Default value for UCS (Uniaxial compressive strength)

Default value for Hoek's M value (0.5 - 7.5)

Default value for Hoek's S value (0.00001 - 0.5)

Default value for tensile strength of INTACT rock (Eg 50)

MESSAGE NUMBER 100

MAIN MENU

0 STOP

1 INITIALIZE DATABASE OR NEW RUN

2 DATA PREPARATION

3 MESH PLOT PREPARATION

4 SPECIAL INPUT/CONTROL OPTIONS

5 NUMBER CRUNCHING

6 PRINT RESULTS

- 7 PREPARE RESULTS FOR PLOTTING
- 8 DIGITIZER UTILITIES
- 9 DOCUMENTATION AND HELP
- 10 ADVANCED UTILITIES

OPTION ?? (EG 9)

SUB-MENU 1 : INITIALIZE DATABASE OR NEW RUN

- 0 STOP
- 1 INITIALIZE EVERYTHING FOR A NEW ANALYSIS
- 2 INITIALIZE STRESSES FORCES AND DISPLACEMENTS
- 3 INITIALIZE DISPLACEMENTS AND STRAINS
- 4 INITIALIZE BOUNDARY CONDITIONS
- 5 DISPLAY VALID KEYWORDS FOR USE IN INPUT DATA FILE
- 6 RETURN TO MAIN MENU

NOTE 2,3 AND 4 ARE AUTOMATICALLY INCLUDED IN 1 ABOVE

Option ?? (EG 4)

SUB-MENU 2 : DATA PREPARATION

- 0 STOP
- 1 READ IN DATA FILE OF NODES AND ELEMENTS
- 2 DOUBLE UP A MESH
- 3 CONVERT A MESH TO AN ASCII FILE FOR BACKUP/EDITING
- 4 LOAD MATERIAL PROPERTIES

NOTE THAT IT IS BETTER TO USE KEYWORD FILE FOR DATA INPUT

- 5 RETURN TO MAIN MENU

OPTION ?? (EG 4)

SUB-MENU 3 : MESH PLOT PREPARATION

- 0 STOP
- 1 DISPLAY INFO ABOUT ELEMENTS AND NODES
- 2 PREPARE A MESH FOR PLOTTING
- 3 PREPARE BOUNDARY CONDITIONS FOR PLOTTING
- 4 PREPARE PERIMETERS FOR PLOTTING
- 5 RETURN TO MAIN MENU

OPTION ?? (EG 4)

SUB-MENU 4 : SPECIAL INPUT/CONTROL OPTIONS

- 0 STOP
- 1 SET A LINEAR RUN
- 2 SET A NON-LINEAR RUN
- 3 SET PLAIN STRAIN ANALYSIS
- 4 SET PLAIN STRESS ANALYSIS
- 5 SET AN AXI-SYMMETRIC ANALYSIS
- 6 INCREMENT THE CURRENT STEP NUMBER BY 1
- 7 DISPLAY THE NUMBER OF NODES/ELTS/BC'S
- 8 SPARE
- 9 RETURN TO MAIN MENU

OPTION ?? (4)

SUB-MENU 5 : NUMBER CRUNCHING

- 0 STOP
- 1 CALCULATE ELEMENT STIFFNESSES
- 2 CHECK FOR DEAD NODES AND CALCULATE PROFILE OF EQUATIONS
- 3 ASSEMBLE EQUATIONS
- 4 SOLVE EQUATIONS
- 5 BACK SUBSTITUTION
- 6 CALCULATE STRESSES AND STRAINS AT ELEMENTS
- 7 CALCULATE NODAL FORCES
- 8 CHECK FOR MATERIAL FAILURE
- 9 ALL OF THE ABOVE UNDER BATCH CONTROL
- 10 RETURN TO MENU

OPTION ?? (EG 4)

SUB-MENU 6 : PRINT RESULTS

- 0 STOP
- 1 PRINT THE HEADER PAGE
- 2 PRINT SELECTED ELEMENT GEOMETRY
- 3 PRINT MATERIAL PROPERTIES
- 4 PRINT NODAL RESULTS
- 5 PRINT ELEMENT RESULTS
- 6 PRINT PERIMETER INFORMATION
- 7 PRINT MESH INPUT DATA (NODES AND ELEMENTS)
- 8 PRINT ELEMENTS FOR EACH SUBREGION
- 9 SPARE
- 10 RETURN TO MAIN MENU

OPTION ?? (EG 4)

SUB-MENU 7 : PREPARE RESULTS FOR PLOTTING

- 0 STOP
- 1 PREPARE A MESH PLOT (ALSO SEE MENU 3 ABOVE)
- 2 PREPARE PERIMETERS FOR PLOTTING
- 3 PREPARE ELEMENT RESULTS FOR PLOTTING
- 4 PREPARE NODAL RESULTS FOR PLOTTING
- 5 PREPARE A DEFORMED MESH FOR PLOTTING
- 6 SPARE
- 7 RETURN TO MAIN MENU

OPTION ?? (EG 4)

SUB-MENU 8 : DIGITIZER UTILITIES

- 0 STOP
- 1 SET UP DIGITIZER AND PLAN SCALES
- 2 DIGITIZE NODAL COORDINATES
- 3 DIGITIZE THE NODES FOR SELECTED ELEMENTS
- 4 DIGITIZE NODAL BOUNDARY CONTITIONS
- 5 DIGITIZE NODES DEFINING A CONTOUR
- 6 DIGITIZE OUTLINES FOR PLOTTING
- 7 DISPLAY/CHECK NODES, ELTS AND BOUNDARY CONDITIONS
- 8 RETURN TO MAIN MENU

OPTION ?? (EG 4)

SUB-MENU 9 : DOCUMENTATION AND HELP

- 0 STOP
- 1 LIST AVAILABLE KEYWORDS FOR DATAFILE PREPARATION
- 2 SPARE COMMANDS
- 3 RETURN TO MAIN MENU

OPTION ?? (EG 4)

SUB-MENU 10 : ADVANCED UTILITIES

- 0 STOP
- 1 DISPLAY/CHECK SELECTED NODES/ELEMENTS
- 2 DISPLAY ELEMENT INFO (for debugging)
- 3 DISPLAY ARRAYS IN FILE QUAD.ARR (for debugging)
- 4 DISPLAY FILESTATUS AND SWITCH REGISTERS (debugging)
- 5 LOAD IN A NEW MESSAGE FILE
- 6 DISPLAY OR MODIFY MESSAGES
- 7 PRINTOUT MESSAGES
- 8 RETURN TO MAIN MENU

OPTION ?? (EG 4)

OPTIONS FOR PLOT PREPARATION

- 0 STOP
- 1 HORIZONTAL AND VERTICAL DISPLACEMENTS
- 2 HORIZONTAL AND VERTICAL STRESSES
- 3 MINIMUM AND MAXIMUM PRINCIPAL STRESSES
- 4 MAXIMUM SHEAR STRESS AND CORRESPONDING NORMAL STRESS
- 5 EXTENSION STRAINS
- 6 HOEKS FAILURE CRITERION
- 7 EXCESS PORE WATER PRESSURE AND RU FACTOR (NOT AVAILABLE)
- 8 RETURN TO MAIN MENU

OPTION ?? (EG 4)

MESSAGE NUMBER 300 --- messages 301 to 400 for error messages

Maximum number of nodes has been exceeded
Maximum number of elements has been exceeded
Maximum number of joint sets has been exceeded
Maximum allowed bandwidth has been exceeded
Invalid node number
Invalid element number
Invalid element/material type code
Invalid boundary condition code
Invalid contour number
Invalid message number
Invalid option --- try again
More than 4 nodes for this element
End of data file
File cannot be opened successfully
Message cannot be accessed
File cannot be accessed
Invalid pen number
Number of bandwidth errors encountered is
Error in global matrix assembly
Column error 1 in back substitution
Warning --- angle at this node may be wrong
Error --- zero or negative area for this element
Warning --- poor aspect ratio for this element
Warning --- element is triangular
Warning --- element is a spring element
Illegal node numbering for this element
Warning --- the shape of this element is poor
Error --- Duplicate nodes for this element
Error --- Unspecified node
Error in subroutine SHAPE -- Invalid intrinsic coordinates
Error --- polygon cannot be processed --- check its shape
Column error 2 in back substitution
Error --- cannot access disk file containing global matrix
Error --- invalid keyword
Error --- keyword does not exist
Warning --- Poissons ratio exceeds 0.49

Warning --- more than 5 neighbours for this node
 Array number to be displayed (1 to 20 ?)
 Skip zero values ??? (Y/N)
 Threshold value for skipping near zero values (Eg 0.01)

Error --- cannot access file on channel 21
 Error --- cannot access file on channel 22
 Error --- cannot access file on channel 23
 Error --- cannot access file on channel 24
 Error --- cannot access file on channel 25
 Error --- cannot access file on channel 26
 Error --- cannot access file on channel 27
 Error --- cannot access file on channel 28
 Error --- cannot access file on channel 29
 Error --- cannot access file on channel 30
 Error --- cannot access file on channel 31
 Error --- cannot access file on channel 32
 Error --- cannot access file on channel 33
 Error --- cannot access file on channel 34
 Error --- cannot access file on channel 35
 Error --- cannot access file on channel 36
 Error --- cannot access file on channel 37
 Error --- cannot access file on channel 38
 Error --- cannot access file on channel 39
 Error --- cannot access file on channel 40
 Error --- cannot access file on channel 41
 Error --- cannot access file on channel 42
 Error --- cannot access file on channel 43
 Error --- cannot access file on channel 44
 Error --- cannot access file on channel 45
 Error --- cannot access file on channel 46
 Error --- cannot access file on channel 47
 Error --- cannot access file on channel 48
 Error --- cannot access file on channel 49
 Error --- cannot access file on channel 50
 Error --- cannot access file on channel 51
 Error --- cannot access file on channel 52
 Error --- cannot access file on channel 53
 Error --- cannot access file on channel 54
 Error --- cannot access file on channel 55

Number	Array	Size	Start	Dimension
1	X	2	1	1536
2	Y	2	3	1536
3	U	2	5	1536
4	V	2	7	1536
5	BCX	2	9	1536
6	BCY	2	11	1536
7	UTOTX	2	13	1536
8	UTOTY	2	15	1536
9	IBC	1	17	1536
10	MATEL	1	19	1536
11	NODEL	4	21	6144
12	ID	2	29	3072
13	JDIAG	2	33	3072
14	ISORT	1	37	1536
15	FX	2	39	1536

16	FY	2	41	1536
17	IDUMP	1	43	1536
18	FXTOT	2	45	1536
19	FYTOT	2	47	1536
20	IGRAV	1	49	1536

Valid keywords are as follows

STOP STOP EXECUTION
 MENU GET THE INTERACTIVE MENU
 HELP GIVE THE USER HELP -- IF AVAILABLE
 START START A TOTALLY NEW RUN -- INITIALIZE EVERYTHING
 STIFF UPDATE THE STIFFNESS (AFTER CHANGES TO MATERIAL TYPES)
 DATA CHANGE TO A NEW DATA FILE (Filename entered from keyboard)
 PERI READ SEQUENCES OF NODES DEFINING PERIMETERS
 RUN START EXECUTING FOR CURRENT STEP
 NODES START READING NODES
 ELTS START READING ELEMENTS
 MATP START READING MATERIAL PROPERTIES
 BC START READING BOUNDARY CONDITIONS AT NODES
 LIN SET A LINEAR RUN
 EX DEFINE STRESSES AROUND EXCAVATION PERIMETERS
 NLIN SET A NON-LINEAR RUN
 STEP READ IN MULTI STEP INFORMATION
 INIT INITIALIZE STRESSES, DISPLACEMENTS, STRAINS AND FORCES
 ISSW DEFINE INTEGER SWITCHES
 SSW DEFINE REAL SWITCHES
 PRIM READ IN PRIMITIVE STRESS CONDITIONS
 OUT1 PRINT OUT HEADER INFORMATION
 OUT2 PRINT NODE/ELEMENT GEOMETRY FOR EASY RE-INPUT
 OUT3 PRINT SELECTED ELEMENT GEOMETRY
 OUT4 PRINT OUT MATERIAL PROPERTIES
 OUT5 PRINT OUT NODAL SOLUTIONS
 OUT6 PRINT OUT ELEMENT SOLUTIONS
 OUT7 PRINT OUT PERIMETER INFORMATION
 OUT8 PRINT OUT ELEMENT/SUBREGION DEFINITIONS
 OUT9

 TNOD TRANSFORM NODES (not yet available)
 FIXM RENUMBER SPECIFIC NODES/ELEMENTS REDUCING BANDWIDTH
 MATEL SPECIFY MATERIAL TYPE FOR EACH ELEMENT
 BOXBC SPECIFY BOUNDARY CONDITIONS TO ALL NODES INSIDE A BOX
 LINBC SPECIFY LINE LOAD BC'S, NODE BY NODE
 ZBC INITIALIZE ALL BC'S TO ZERO
 PAIN PLAIN STRAIN ANALYSIS
 PESS PLAIN STRESS ANALYSIS
 AXIS AXI-SYMMETRIC ANALYSIS
 GRAV ADD GRAVITY LOAD AT SPECIFIED ELEMENTS
 JOINT INPUT JOINT PROPERTIES
 ENDBC END BOUNDARY CONDITION INPUT AND ALSO SET ELEMENT PROPERT
 BUG1 DISPLAY SYSTEM INFO (RELATED TO COMMON BLOCK)
 BUG2 DISPLAY SYSTEM INFO (RELATED TO ARRAYS)
 VIRG ALLOCATE VIRGIN STRESS CONDITIONS TO SELECTED ELEMENTS
 CONT USE A CONTOUR TO SET PRIMITIVE STRESSES AT GIVEN SURFACE

SKIP SELECT ELEMENTS TO BE SKIPPED IN POST PROCESSING
MESH PREPARE MESH FOR PLOTTING
PLBC PREPARE BOUNDARY CONDITIONS FOR PLOTTING
DOUBLE DOUBLE UP A MESH
DIGIT ENTER THE DIGITIZER MENU

....
HEAD READ IN USER HEADING/PROBLEM DESCRIPTION
NONI INPUT NON-LINEAR ITERATION PARAMETERS
DEFM DEFORMED MESH PLOT PREPARATION
ELTP PREPARE ELEMENT RESULTS FOR PLOTTING
NODP PREPARE NODAL RESULTS FOR PLOTTING
PERP PREPARE PERIMETERS FOR PLOTTING

LAST LAST KEYWORD AVAILABLE SEE GETKEY

Different keywords are used at different times in the program
Some keywords always apply
Some are used for node and element geometry input! and editing
Some are used for materials and BC input
Some are used for printout control
It is better and sometimes essential to run program under
keyword control, rather than menu control.
Menu control is mainly for de-bugging and post processing

MESSAGE NUMBER 500
NUMBER OF NODES
NUMBER OF ELEMENTS
NUMBER OF MATERIAL TYPES
NUMBER OF ITERATIONS FOR NON-LINEAR SOLUTIONS
PLAIN STRESS(1) PLAIN STRAIN (2) AXI-SYMMETRIC (3)
NDIMD --- ARRAY DIMENSION -- 3 FOR PLAIN OR 4 FOR AXI-SYMMETRIC CONSTANT
PRIMITIVE STRESS IN X DIRECTION
CONSTANT PRIMITIVE STRESS IN Y DIRECTION
CONSTANT PRIMITIVE SHEAR STRESS
DEPTH VARIATION OF PRIMITIVE STRESS IN X-DIRECTION
DEPTH VARIATION OF PRIMITIVE STRESS IN Y DIRECTION
DEPTH VARIATION OF PRIMITIVE SHEAR STRESS
Acceleration factor for Non-linear iterations
Convergence limit for non-linear iterations (Units of stress)
Scale factor to be applied to displacements
First perimeter number in this sequence
Last perimeter number in this sequence

Nodes are sorted in order of increasing distance from a point
Enter X-coord of this point
Enter Y-coord of this point
Enter shrinkage factor for element geometry
Recommended value is 0.98 for big plots, 0.96 for small plots
If node are to be plotted as well, try 0.8
Do not use less than 0.7 or greater than 1.0

Select option for pen colours

- 0 No pen colour selection
- 1 Select pen colours interactively
- 2 Select pen colours from the materials master file

Note Only use option 2 once you have created the materials file

Select option for plotting of nodes/elements

- 0 Plot nothing at each node/element location
- 1 Plot number at each node/element location
- 2 Plot X at each node/element location

This module will prepare boundary conditions for plotting

Information will be stored in file 'QUAD.PN'

Select the required option

- 0 Return to menu:
- 1 Plot boundary condition code at relevant nodes
- 2 Plot 'X' at each boundary condition node

Now start with nodes

Start with elements

Start checking nodes

Start checking elements

Air or dead element

Dead node

Number of dead nodes

Node number for boundary condition (or 0 to end)

Boundary condition code (1 to 4)

X-value of boundary condition (or 0)

Y-value of boundary condition (or 0)

Calculate profile of equations

Assemble equations

Solve equations

Average bandwidth

Maximum bandwidth

Calculate element stresses

Calculate nodal forces/reactions

Calculate excess stresses

Iteration number

Current mining step number

Prepare perimeters for plotting

Prepare a deformed mesh for plotting

Prepare a mesh for plotting

Prepare element results for plotting

Prepare boundary conditions for plotting

A linear run has been specified

A non-linear run has been specified

MESSAGE NUMBER 600

Each point digitized to be beeped ??? (Y/N)

When digitizing points, the digitized point need not coincide with the actual point. You may enter a distance threshold within which points are accepted.

If point is within threshold then an extra bell sounds.
Otherwise the closest nodal point will be used.
Note that if a big threshold distance is specified you may not always locate the correct point.
Enter your required threshold distance in M. (eg 0.1)
You may autosave nodes/elements onto disk as they are digitized
This can be useful if a problem arises during digitizing
The autosave process slows down the digitizing slightly.
Enter number of nodes/elements to be digitized between autosaves (suggested value is between 50 and 200) :

Digitizer interfaces are defined by the users :
Each digitizer is specified in file a:digit.fil
The DOS MODE command must also be used to define baud rate etc.
At present, Summagraphics, GTCO and Calcomp digitizers have been used successfully

Node number
Node has been moved okay

Procedure to be followed if the digitizer does not work

1. Check that the digitizer cable is connected to the right computer
2. Check that the digitizer control panel is switched on and has been set for point digitizing
3. Check that the dos MODE command has been used correctly
4. Check that the definition of file DIGIT.FIL is correct
5. Rack your brains for other possible problems

Digitize 4 dummy points now test the digitizer

The mesh must be placed on the digitizer so that

1. + X coordinates increase from left to right
- X coordinates increase from right to left
2. + Y coordinates increase from bottom to top
- Y coordinates increase from top to bottom

You must now digitize 4 control points in a rectangle
Usually the rectangle will encompass all your nodes and elements
You may, however, digitize points outside of this rectangle.
You should make your control rectangle as large as is convenient
Each corner of the rectangle must now be digitized (any button)
Digitize Bottom Left corner now
Digitize Top Right corner now
Digitize Bottom Right corner now
Digitize Top Left corner now

Now enter the coordinates of the Bottom Left corner
X-coordinate
Y-coordinate
Now enter the coordinates of the Top Right corner

Scale factors and paper stretch have now been calculated
Scale factor in X direction is 1:
Scale factor in Y direction is 1:
Distortion in transformation in % is
If this value exceeds 2.5 % you should redo the rectangle
DO YOU WISH TO REDO THE CALIBRATION (Y/N)

Options for digitizing nodes

- 1 Digitize NODES
- 2 Specify the first node number of a new sequence (or END)
- 3 Move the nearest node to the point digitized (edit nodes)
- 4 Return to menu
Enter the node number of the next point to be digitized
Latest results are now being saved

Options for digitizing elements

- 1 Digitize the centroid of an element (then use 2)
- 2 3 or 4 nodes around an element (use after 1)
- 3 Digitize ELEMENTS (Automatic mode for VERY regular elements)
- 4 Return to menu
Enter the number of the next element to be digitized

Quadrilateral element

Triangular element

Error --- less than three nodes for this element

- 4 IS ALSO FOR ENDING OFF

Options for digitizing boundary conditions

- 1 Forces in X and Y directions
- 2 X-force and Y-displacement (usually bottom of mesh)
- 3 Y-force and X-displacement (usually sides of mesh)
- 4 Displacements in X and Y directions (usually at corners)

NOTE ONLY FOR BC CODES, NOT ACTUAL FORCE VALUES

You have two ways to digitize boundary conditions

1. Enter X and Y boundary values for a sequence of points
2. Enter X and Y boundary values for each point

MESSAGE NUMBER 700

You will usually use option 1 for sides and base of a mesh
and option 2 for specifying special loads

Enter required option

Enter X boundary condition of points to follow (or 0)

Enter Y boundary condition of points to follow (or 0)

Enter X boundary condition of point just digitized (or 0)

Enter Y boundary condition of point just digitized (or 0)

Options for digitizing contours

- 1 First and subsequent points along the contour
- 2 Last point of an OPEN contour (or return to menu)
- 3 Last point of a CLOSED contour (or return to menu)
- 4 Erase previous point digitized

Deleted : node number

Number of points in contour just digitized is

Enter the record number to save this contour (or 0 to skip)

Current number of contours already saved is :

Options for digitizing plot lines/points

- 1 Draw to this node from previous point
- 2 Move to this node from previous point
- 3 Plot an X or node number at this node
- 4 Change pen colour or end

The Button # 1 is for one of the following options

- 1 Plot the node number of the nearest node
- 2 Plot an X at the nearest node
- 3 Plot an X at the actual point digitized
- 4 spare
- 5 spare

Select required option (enter 1 if not sure)

You may now display to the screen data base info as follows

- 1 Node coordinates
- 2 Elements and their nodes
- 3 Boundary conditions

Enter selected option (or 0 to return to menu)

Start number of a sequence

Stop number of a sequence

Note that if you insert/delete an element, subsequent elements will be renumbered. This could seriously affect material properties or other input data. Therefore, this option should be used during initial mesh preparation.

Enter element number to be inserted

Enter element number to be deleted

ENTER 1 TO CONTINUE OR 0 TO RETURN TO MENU

ENTER PEN NUMBER 1,2,3,..

DIGITIZE POINTS NOW

You may now reset the maximum number of nodes,elements, etc

Enter 0 for the next questions to leave unaltered

New number of nodes ???

New number of elements ???

New number of Contours ???

Enter vertical exaggeration factor to help the program to find the correct nearest nodes.

For example if elements are three times wider than high then a vertical factor of 2 or 3 is appropriate.

The default value is 1 (enter this value if uncertain)

Enter your vertical exaggeration factor (0.01 to 100) :

MESSAGE NUMBER 800

MESSAGE NUMBER 900

APPENDIX B

Keywords

TABLE OF CONTENTS

B-1	KEYWORDS IN QUAD AND THEIR FORMAT	B-1
B-2	VARIABLES USED FOR KEYWORD INPUT	B-2
B-3	DESCRIPTION OF KEYWORDS	B-5

LIST OF FIGURES

B.1	Illustration of Planes Symmetry	B-7
B.2	Illustration of Planes Symmetry with Geological Discontinuities	B-8
B.3	Deformed Shape of a Concrete Gravity Dam	B-15
B.4	Digitized Mesh Showing some Errors	B-17
B.5	Coal Longwall Simulation	B-21
B.6	Non-linear Test Problem	B-22
B.7	Example of a Mesh for a Circular Tunnel	B-24
B.8	Underground Mining Solution	B-25
B.9	FEM Analysis Concrete Gravity Dam Using 'QUAD'	B-26
B.10	Buried Pipe Analysis	B-42
B.11	Non-linear Test Problem Flow Vectors for Compressible Flow/Distorsion	B-44
B.12	Effective Haunching Analysis	B-49
B.13	Estimated K-Ratio Gradient	B-66
B.14	Estimated Vertical Stress Gradient	B-67
B.15	Comparison Between Estimated Virgin K-Ratio and Induced K-Ratio	B-68
B.16	Comparison Between Estimated Vertical Virgin Stress and Induced Stress	B-69
B.17	Geometry and Material Properties for Joint Example	B-79
B.18	Geometry and Material Properties for Non-linear Test Problem	B-80
B.19	Outer Mesh for Circular Tunnel	B-82

LIST OF TABLES

B.1	Element Numbering Checker	B-18
B.2	Choices for Values to Plot Nodes	B-47
B.3	Choices for Values to Plot Elements	B-48
B.4	Non-linear Material Types and Output Parameters	B-78

B-1 KEYWORDS IN QUAD AND THEIR FORMAT

Quad is best run through a file that contains keywords and any data that these keywords need. This option saves the user time, and is much like running a program through a batch file.

The following is a list of the keywords that Quad uses, and a short description of each. After the list follows a detailed description of the input and format of all keywords.

<u>KEYWORD</u>	<u>DESCRIPTION</u>
START	START A TOTALLY NEW RUN -- INITIALIZE EVERYTHING
STOP	STOP EXECUTION
INIT	INITIALIZE STRESSES, DISPLACEMENTS, STRAINS AND FORCES
STEP	READ IN MULTI STEP INFORMATION
RUN	START EXECUTING NUMBER CRUNCHING FOR THE CURRENT STEP
DIGIT	ENTER THE DIGITIZER MENU
DATA	CHANGE TO A NEW DATA FILE (Filename entered from keyboard)
MENU	GET THE INTERACTIVE MENU
HELP	GIVE THE USER HELP -- IF AVAILABLE
HEAD	READ IN USER HEADING/PROBLEM DESCRIPTION
NODES	START READING NODES
TNOD	TRANSFORM NODES
ELTS	START READING ELEMENTS
TELT	TRANSFORM ELEMENTS
DOUBLE	DOUBLE UP A MESH
MATP	START READING MATERIAL PROPERTIES
MATEL	SPECIFY MATERIAL TYPE FOR EACH ELEMENT
STIFF	UPDATE THE STIFFNESS (AFTER CHANGES TO MATERIAL TYPES)
PRIM	READ IN PRIMITIVE STRESS CONDITIONS
CONT	USE A CONTOUR TO SET PRIMITIVE STRESSES AT GIVEN SURFACE
VIRG	ALLOCATE VIRGIN STRESS CONDITIONS TO SELECTED ELEMENTS
GRAV	ADD GRAVITY LOAD AT SPECIFIED ELEMENTS
PERI	READ SEQUENCES OF NODES DEFINING PERIMETERS
EX	DEFINE STRESSES AROUND EXCAVATION PERIMETERS
ZBC	INITIALIZE ALL BC'S TO ZERO
BC	START READING BOUNDARY CONDITIONS AT NODES
BOXBC	SPECIFY BOUNDARY CONDITIONS TO ALL NODES INSIDE A BOX
LINBC	SPECIFY LINE LOAD BC'S, NODE BY NODE
ENDBC	END BOUNDARY CONDITION INPUT AND ALSO SET ELEMENT PROPERTIES
JOINT	INPUT JOINT PROPERTIES
LIN	SET A LINEAR RUN
NLIN	SET A NON-LINEAR RUN
NONI	INPUT NON-LINEAR ITERATION PARAMETERS

PAIN	PLAIN STRAIN ANALYSIS
PESS	PLAIN STRESS ANALYSIS
AXIS	AXI-SYMMETRIC ANALYSIS
ISSW	DEFINE INTEGER SWITCHES
SSW	DEFINE REAL SWITCHES
SKIP	SELECT ELEMENTS TO BE SKIPPED IN POST PROCESSING
NODP	PREPARE NODAL RESULTS FOR PLOTTING
ELTP	PREPARE ELEMENT RESULTS FOR PLOTTING
MESH	PREPARE MESH FOR PLOTTING
DEFM	DEFORMED MESH PLOT PREPARATION
PERP	PREPARE PERIMETERS FOR PLOTTING
PLBC	PREPARE BOUNDARY CONDITIONS FOR PLOTTING
BUG1	DISPLAY SYSTEM INFO (RELATED TO COMMON BLOCK)
BUG2	DISPLAY SYSTEM INFO (RELATED TO ARRAYS)
OUT1	PRINT OUT HEADER INFORMATION
OUT2	PRINT NODE/ELEMENT GEOMETRY FOR EASY RE-INPUT
OUT3	PRINT SELECTED ELEMENT GEOMETRY
OUT4	PRINT OUT MATERIAL PROPERTIES
OUT5	PRINT OUT ELEMENT SOLUTIONS
OUT6	PRINT OUT NODAL SOLUTIONS
OUT7	PRINT OUT PERIMETER INFORMATION
OUT8	PRINT OUT ELEMENT/SUBREGION DEFINITIONS
OUT9	
LAST	LAST KEYWORD AVAILABLE SEE GETKEY

B-2 VARIABLES USED FOR KEYWORD INPUT

All variables in following pages refer to this list.

<u>VARIABLES</u>	<u>DESCRIPTION</u>
NLIN1	Number of lines (nodes) of data which follow (of 1 line each) (not to be confused with variable NLIN)
NLIN2	Number of pairs of lines which follow
NLIN3	Number of sets of 3 lines each which follow
IFROM	From element number (for a loop)
ITO	To element number (for a loop)
NFROM	From node number (for a loop)
NTO	To node number (for a loop)
I	Element number
N	Node number
N1,N2,N3,N4	Node numbers
X	X coordinate of node
Y	Y coordinate of node
PXX	Constant portion of primitive stresses in X direction

PYY	Constant portion of primitive stresses in Y direction
PXY	Constant portion of primitive shear stress
DXX	Depth dependent portion of primitive stresses in X direction
DYY	Depth dependant portion of primitive stresses in Y direction
DXY	Depth dependant portion of primitive shear stress
NITER	Number of iteration for non-linear solution (maximum)
OMEGA	Acceleration factor for non-linear solution. Relaxation factor for convergence (1 to 1.5)
DEL	Convergence limit (in term of strain). Final maximum stress imbalance for convergence of non-linear analyses. Units as for Youngs Modulus
CHAR	Heading or description up to 64 characters
K	Subregion number for material properties
UNITW	Unit weight of material (to be given a negative sign if Y + points up)
E	Youngs Modulus (parallel to isotropic plane is anisotropic.
V	Poisson ratio
E2	Second modulus for anisotrope material
V2	Second Poisson ratio for anisotropic material
G2	Shear modulus for anisotropic material
ANISO	Angle of anisotropy measured from +X to +Y. Note: $E2-V2-G2 = ANISO = 0$ for isotropic material
MTYP	Material type code (0 to 999)
P1	First parameter describing non-linear material
P2	Second parameter describing non-linear material
P3	Third parameter describing non-linear material
P4	4th parameter describing non-linear material
P5	5th parameter describing non-linear material
MPEN	Pen number for plotting the material
XMIN	Minimum X coordinate for a rectangle
XMAX	Maximum X coordinate for a rectangle
YMIN	Minimum Y coordinate for a rectangle
YMAX	Maximum Y coordinate for a rectangle
J	Boundary condition code (0 to 4)
BCX	Boundary value in X direction (force or displacement)
BCY	Boundary value in Y direction (force or displacement)
NGROUPS	Number of groups of lines of data index each group of data may have variable length
NPERI	Number of nodes in a perimeter
IPERI	Perimeter number being defined
SXX	Boundary stress in X direction
SYX	Boundary stress in Y direction
SXY	Boundary shear stress
KODEX	Code defining type of loading on excavation perimeter
ISW	Integer switch number
IVAL	New integer value
JS	Joint set number
CJ(JS)	Cohesion for joint

PHJ(JS)	Friction angle for JS
ALJ(JS)	Orientation (in degrees from +X direction to +Y direction)
TJ(JS)	Tensile strenght of joint
CONJ(JS)	Continuity factor for joints (0 to 1) 1 : fully continuous 2 : fully discontinuous
SRJ(JS)	Average spacing (in metres)
RCJ(JS)	Residual cohesion
CCJ(JS)	Continuity coefficient describing relative offset to intact rock because of the presence of joints (0.01 to 0.1)
BJ(JS)	Shear strength reductive factor

B-3 DESCRIPTION OF KEYWORDS

Keyword AXIS

Purpose AXI-SYMMETRIC ANALYSIS

Format AXIS

Example AXIS

Notes

Subroutine
QUADKEY

Menu Option
4.5

When Necessary
Input

Reference
41

Keyword BC

Purpose START READING BOUNDARY CONDITIONS AT NODES

Format BC

NLIN1

N, J, BCX, BCY

N, J, BCX, BCY

etc.

Example BC

5

11, 3, 0, 0

12, 3, 0, 0

13, 2, 0, 0

14, 4, 0, 0

17, 1, 0, -5

Notes

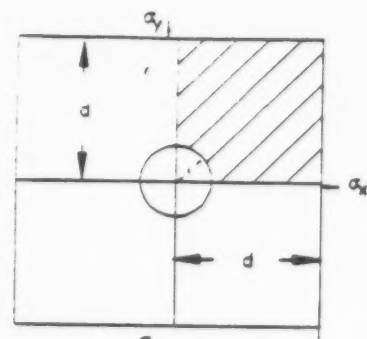
1. NLIN1 is the number of nodes that follow to have their boundary conditions set. N is the node number. J is a boundary condition outlined below.
2. Boundary conditions codes (J) are as follows:
 - 1 Apply forces in X and Y directions
 - 2 Specify x-force and y-displacements
 - 3 Specify x-displacements and y-force
 - 4 Specify x and y-displacements
3. Usually use code 2 on base of mesh and maybe top as well.
Usually use code 3 on side of mesh.
Usually use code 4 on corners of mesh.
4. BCX and BCY are the boundary value in X+Y directions for forces or displacements at the given node.

Subroutine
INBC

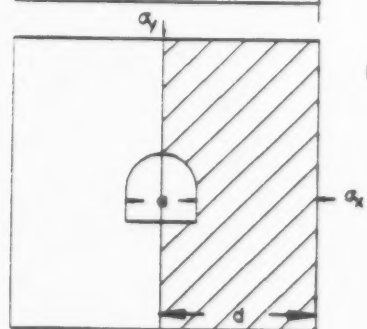
Menu Option

When Necessary
Input

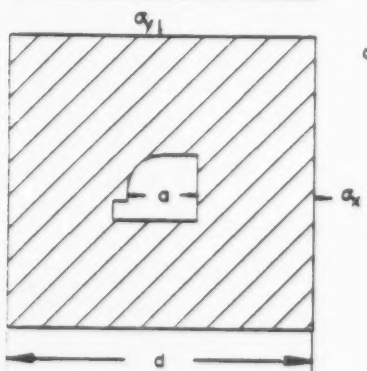
Reference
12



- a. Two planes of symmetry only one quadrant needs to be modelled.
 $d \geq 10r$ displacement on planes of symmetry to be specified as indicated.

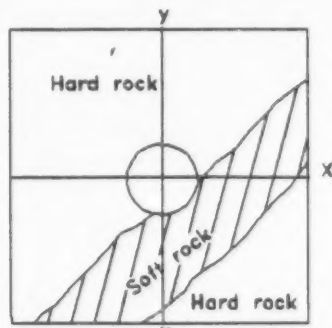


- b. One plane of symmetry only one half needs to be modelled.
 $d \geq 10a$ displacement on plane symmetry to be specified as indicated.

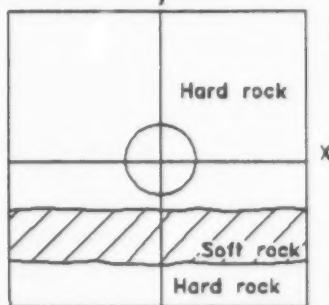


- c. No planes symmetry model completely
 $d \geq 10a$

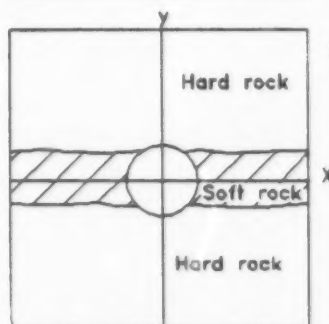
Figure B.1: Illustration of Planes Symmetry



a. No planes of symmetry complete structure must be modelled.



b. Y-Y plane is a plane symmetry.
Only one half need to be modelled.



c. Both X-X and Y-Y are planes of symmetry
only one quadrant needs to be modelled

Figure B.2: Illustration of Planes of symmetry with geological Discontinuities

Keyword BOXBC

Purpose SPECIFY BOUNDARY CONDITIONS TO ALL NODES INSIDE A BOX

Format BOXBC

XMIN, XMAX, YMIN, YMAX, J

XMIN, XMAX, YMIN, YMAX, J

0, 0, 0, 0, 0

Example BOXBC

-0.1, +0.1, -0.1, 100.1, 3

99.9, 100.1, -0.1, 100.1, 3

-0.1, 100.1, -0.1, 1.1, 2

0, 0, 0, 0, 0

Notes

1. One line of data specifying a window for calculation of stresses and displacements. The default is 0,0,0,0 to have no window. Otherwise stresses and displacements will only be calculated inside this window.
2. BOXBC is a quick way to set the boundary conditions of many nodes at one time.
3. All nodes within the XMIN, XMAX, YMIN, YMAX rectangle are set to the specified boundary condition.
4. If a boundary condition code has already been set to 2 or 3, and is then set to 3 or 2 subsequently, the new code is automatically set to 4 for a fixed corner.

Subroutine
BOXBC

Menu Option

When Necessary
Rectangular meshes.

Reference
36

Keyword BUG1

Purpose DISPLAY SYSTEM INFO (RELATED TO COMMON BLOCK)

Format BUG1

Example BUG1

Notes

1. Displays status of file, real, and integer switches used by Quad. These values are stored in the arrays IFSTATUS, SSW, and ISSW.

Subroutine
Q1004

Menu Option
10.4

When Necessary
As required.

Reference
45

Keyword BUG2

Purpose DISPLAY SYSTEM INFO (RELATED TO ARRAYS)

Format BUG2

Example BUG2

Notes

1. Allows interactive display of various system arrays used in Quad. The arrays are stored in the file QUAD.ARR.
2. The arrays that can be looked at are as follows:

NUMBER		ARRAY DESCRIPTION
1	X	X-coordinates
2	Y	Y-coordinates
3	U	X-displacements
4	V	Y-displacements
5	BCX	X boundary conditions
6	BCY	Y boundary conditions
7	UTOTX	X total displacements
8	VTOTY	Y total displacements
9	IBC	Nodal boundary condition codes
10	MATEL	Material subregion
11	NODEL	Nodes numbers, element numbers
12	ID	Matrix profile index
13	JDIAG	Matrix profile index
14	ISORT	Sort array for nodes
15	FX	Incremental boundary forces
16	FY	Incremental boundary forces
17	IDUMP	Disk dump pointer
18	FXTOT	Total X force
19	FYTOT	Total Y force
20	IGRAV	Gravity on/off

Subroutine
Q1003

Menu Option
10.3

When Necessary
As required.

Reference
46

Keyword CONT

Purpose USE A CONTOUR TO SET PRIMITIVE STRESSES AT GIVEN SURFACE

Format CONT

Example CONT

Notes

1. This option is not available yet.

Subroutine

Menu Option
Not available yet.

When Necessary
48

Reference

Keyword DATA

Purpose CHANGE TO A NEW DATA FILE (Filename entered from keyboard)

Format DATA

Example DATA

Notes

1. After the keyword is read in, you will be prompted for the name of the file you wish to use.

Subroutine	Menu Option	When Necessary	Reference
SETDAT	When data is spread over more than one file.	6	

Keyword DEFM
Purpose DEFORMED MESH PLOT PREPARATION

Format DEFM

Example DEFM

Notes

1. The user is interactively asked which nodes, elements and pens are to be prepared for the deformed mesh plot, as well as the shrinkage factor for elements. (Elements may be plotted slightly smaller so that each element may be viewed separately from it's neighbours.) Displacements may be multiplied by a factor to emphasize the deformation.
2. Plot file containing the deformed mesh is QUAD.PD.
Plot file containing node numbers is QUAD.PN.
Plot file containing element numbers is QUAD.PE.

Subroutine
Q705

Menu Option
7.5

When Necessary
After running Quad
to get the deformed
mesh.

Reference
57

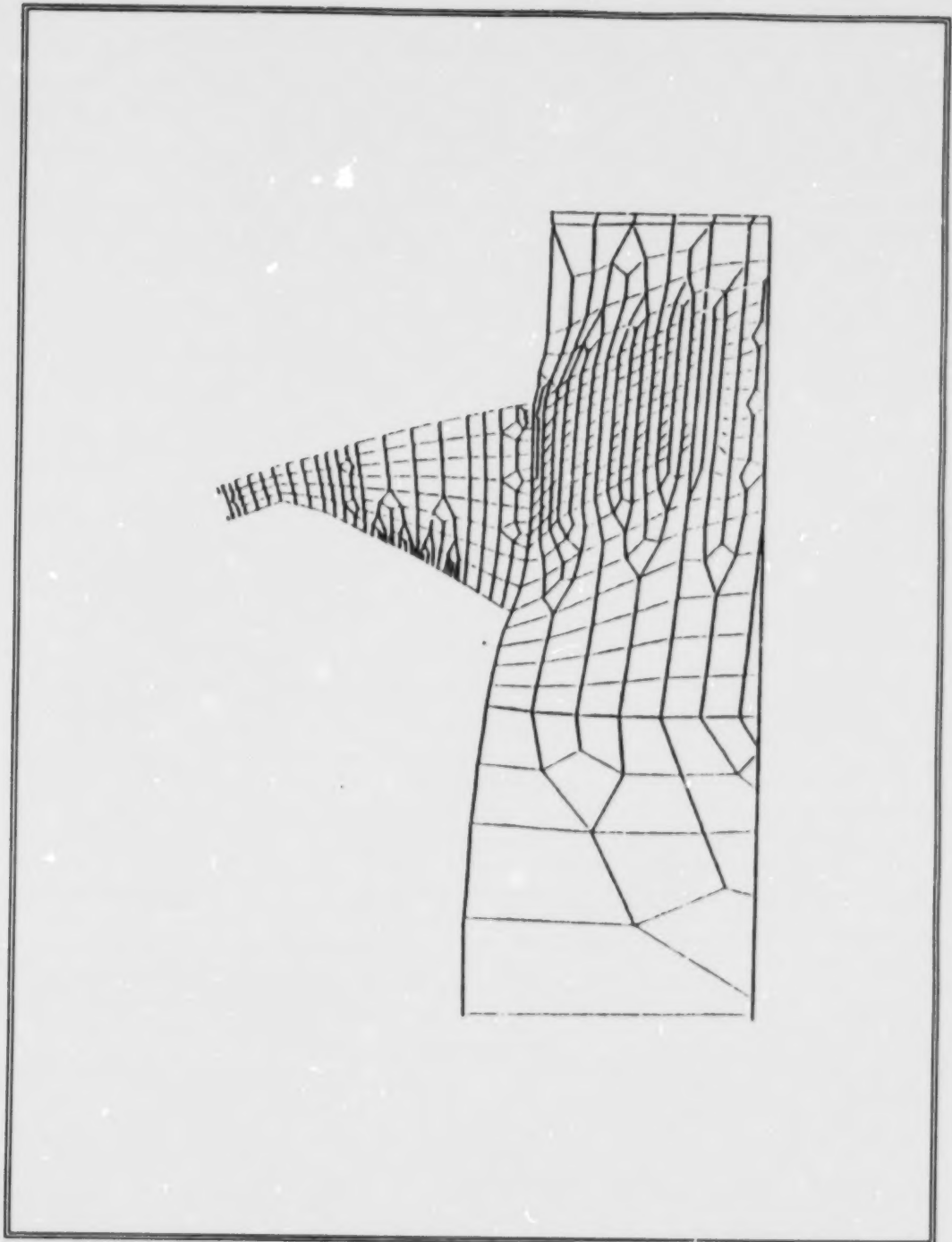


Figure B.3: Deformed Shape of a Concrete Gravity Dam

Keyword DIGIT
Purpose ENTER THE DIGITIZER MENU

Format DIGIT

Example DIGIT

Notes

1. Used to enter the digitizing facility of Quad.

Subroutine
Q800

Menu Option
8

When Necessary
To create node and
element data without
using an editor.

Reference
53

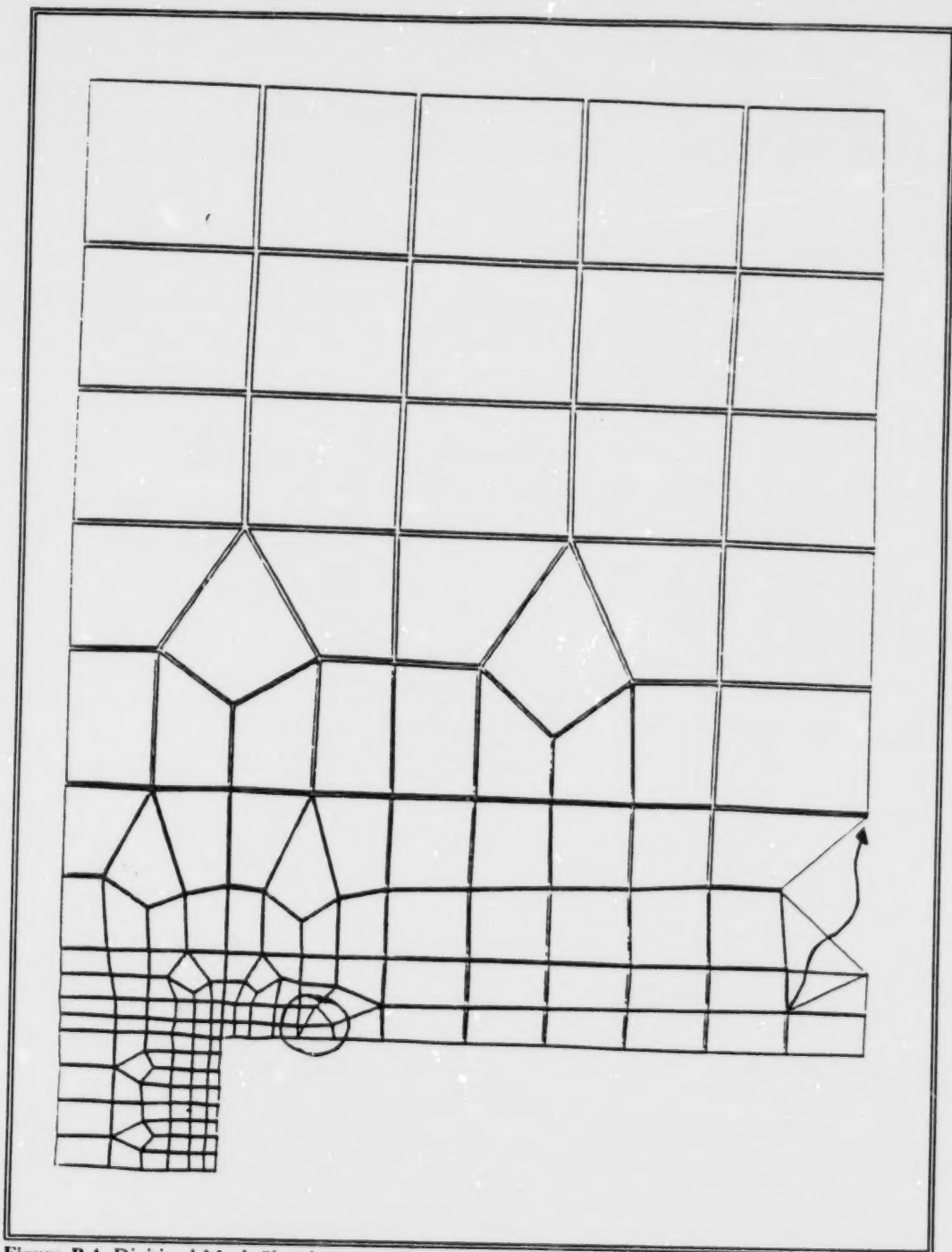


Figure B.4: Digitized Mesh Showing some Errors

Table B.1: Element Numbering Checker

Type	Element	Description of error	Fixable by Quad
1	44,44,55,66	Triangle element with bad order	Yes
2	33,44,44,66	Triangle element with bad order	Yes
3	33,44,55,33	Triangle element with bad order	Yes
4	44,55,44,66	Bad element	No
5	33,44,55,44	Bad element	No
6	44,55,0,66	Illegal zero node	Possible*
7	77,66,55,44	Reverse ordering (clockwise)	Yes
8	77,66,55,55	Reverse ordering for a triangle element	Yes

Keyword DOUBLE
Purpose DOUBLE UP A MESH

Format DOUBLE

Example DOUBLE

Notes

1. After the keyword DOUBLE is read in, the program will double up the nodes and elements. It will then ask you for an (x,y) point to sort the node numbers from, with the smaller node numbers being closest to the point and the larger node numbers being the farthest away from that point.

Subroutine
Q204

Menu Option
2.4

When Necessary
For creating a
finer mesh.

Reference
52

Keyword ELTP

Purpose PREPARE ELEMENT RESULTS FOR PLOTTING

Format ELTP

Example ELTP

Notes

1. Plot options are interactive.
2. Options include stresses, strains, principal stresses and various failure criterion tests.
3. Plot file containing information on stresses, strains, etc. is QUAD.PG.
Plot file containing displacement vectors is QUAD.PV.
Plot file containing stress vectors is QUAD.PS.
4. The following is a short note on values stored in QUAD.PG from the failure test options 11, 12, and 14.

Hoek's FOS value Value ≥ 1.00 No shear failure.
 Value < 1.00 shear failure.

Hoek's excess stresses

Returned value is a stress, negative stresses are compressive, positive are tension. The value returned is how much the value of σ_1 can be changed so that it remains under the Mohr circle curve. If the value is negative (compressive), it means that more stress can be added to that element to have it intersect the Mohr curve. This means no tensile failure has occurred. If the value is positive (tension) then it means stress has to be taken off of the element for it to intersect the curve. This means tensile failure has occurred.

Mohr excess stress

Much the same as the Hoek's analysis, except that instead of the Mohr curve, a straight line approximation to the curve is used.

Subroutine
Q703

Menu Option
7.3

When Necessary
As required.

Reference
58

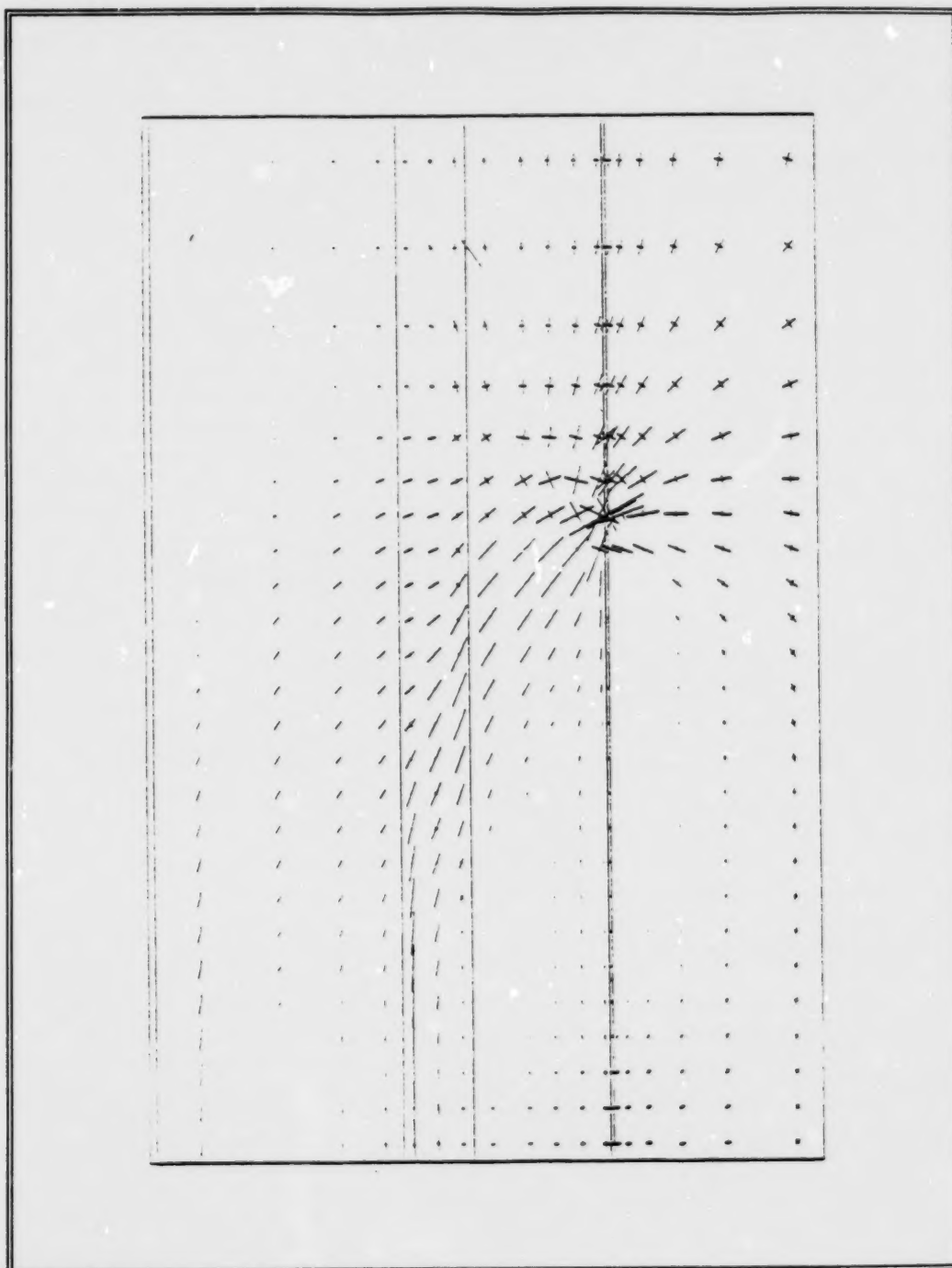


Figure B.5: Coal Longwall Simulation

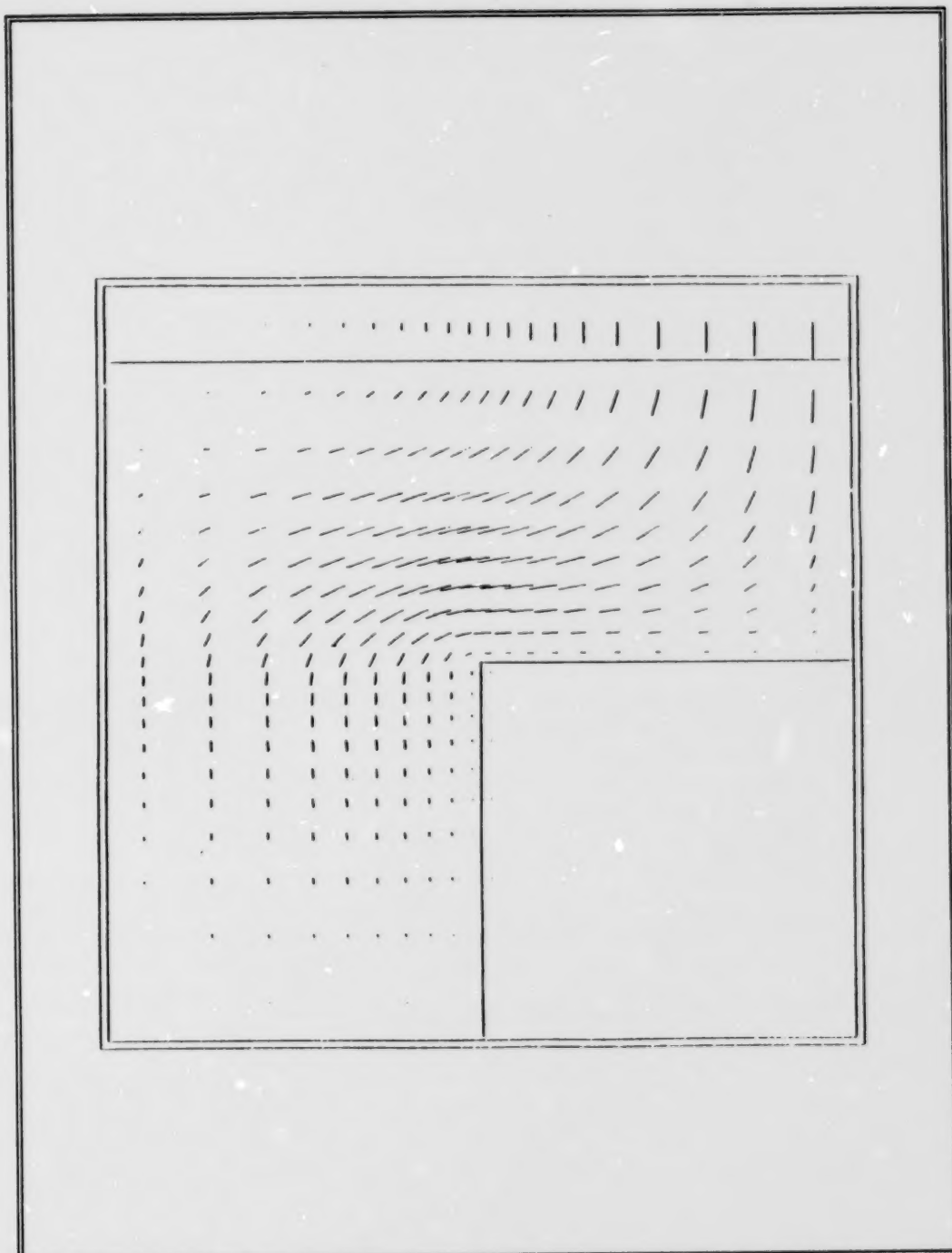


Figure B.6: Non-linear Test Problem

Keyword ELTS

Purpose DEFINE/CHANGE NODES FOR EACH ELEMENT

Format ELTS

NLIN1

I,N1,N2,N3,N4

I,N1,N2,N3,N4

ETC.

Example ELTS

3

1,41,42,48,50

2,61,67,49,48

3,10,12,13,14

ELTS

1000

or16,22,24,25,28

17,22,28,36,0

18,20,21,37,37

19,56,57,58,61

0,0,0,0

Notes

1. Triangular elements have $N4 = N3$ or $N4 = 0$.
See elements 17 and 18 above for example.
2. Input of elements is terminated either when NLIN1 elements have been read or when a data line 0,0,0,0 is encountered.
3. Values may be separated by commas or blanks.
4. The sense of node numbering is from +X axis to +Y axis.
(Usually anti-clockwise.)
5. Maximum number of elements is 1536 elements.

Subroutine
INELT

Menu Option
Input

When Necessary
10

Reference

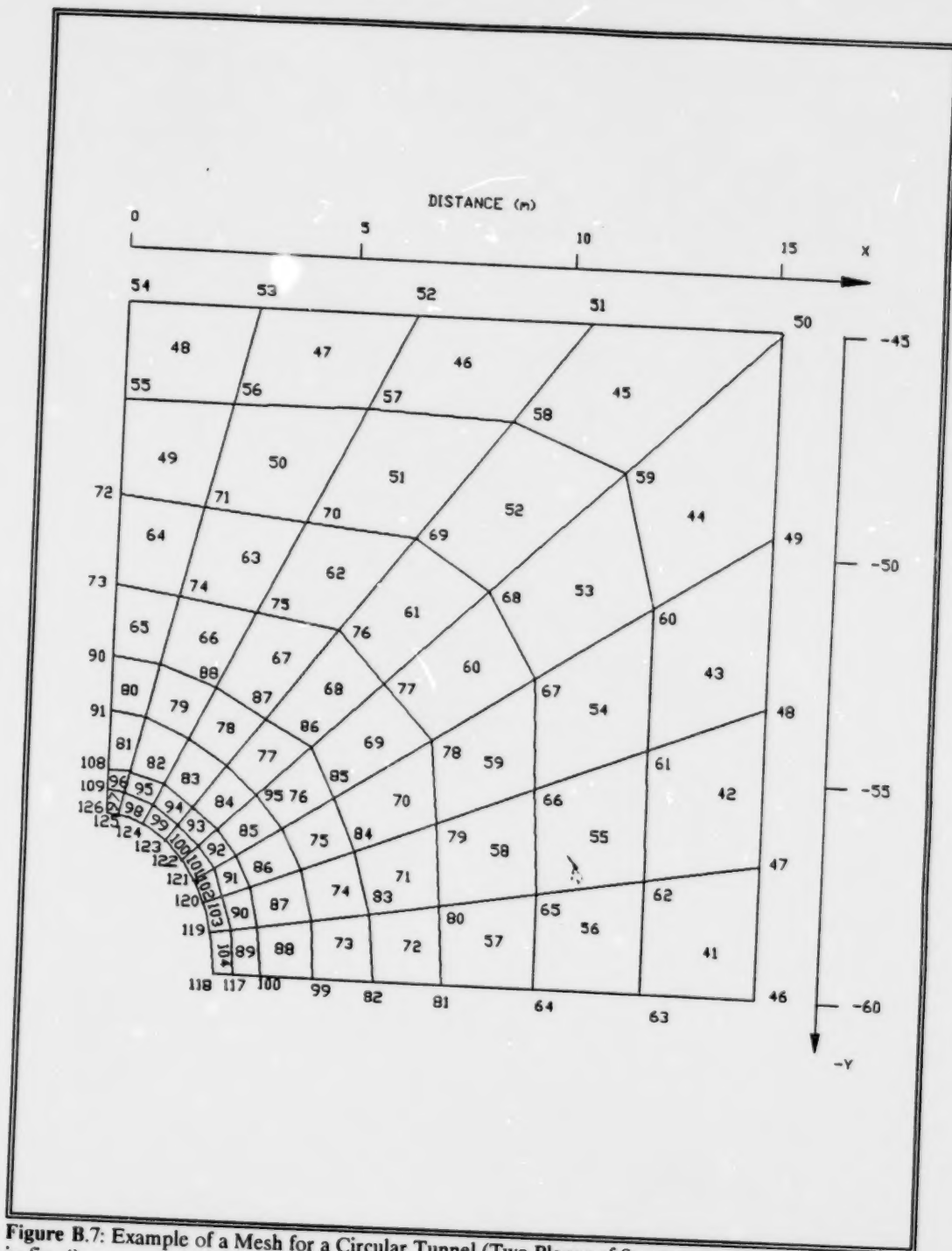


Figure B.7: Example of a Mesh for a Circular Tunnel (Two Planes of Symmetry - See the other portion in fig. 4)

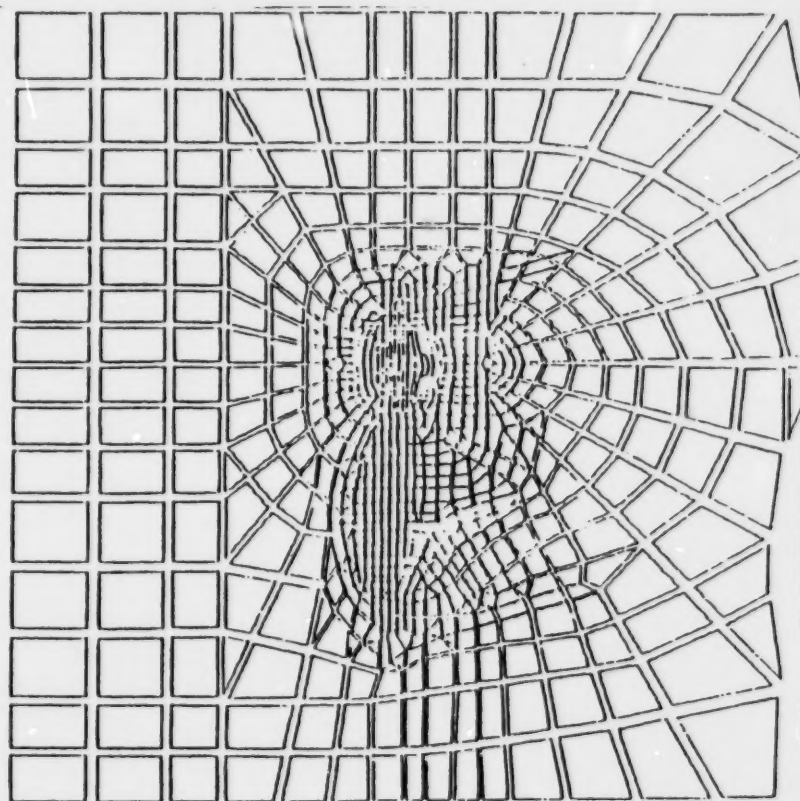


Figure B.8: Underground Mining Simulation

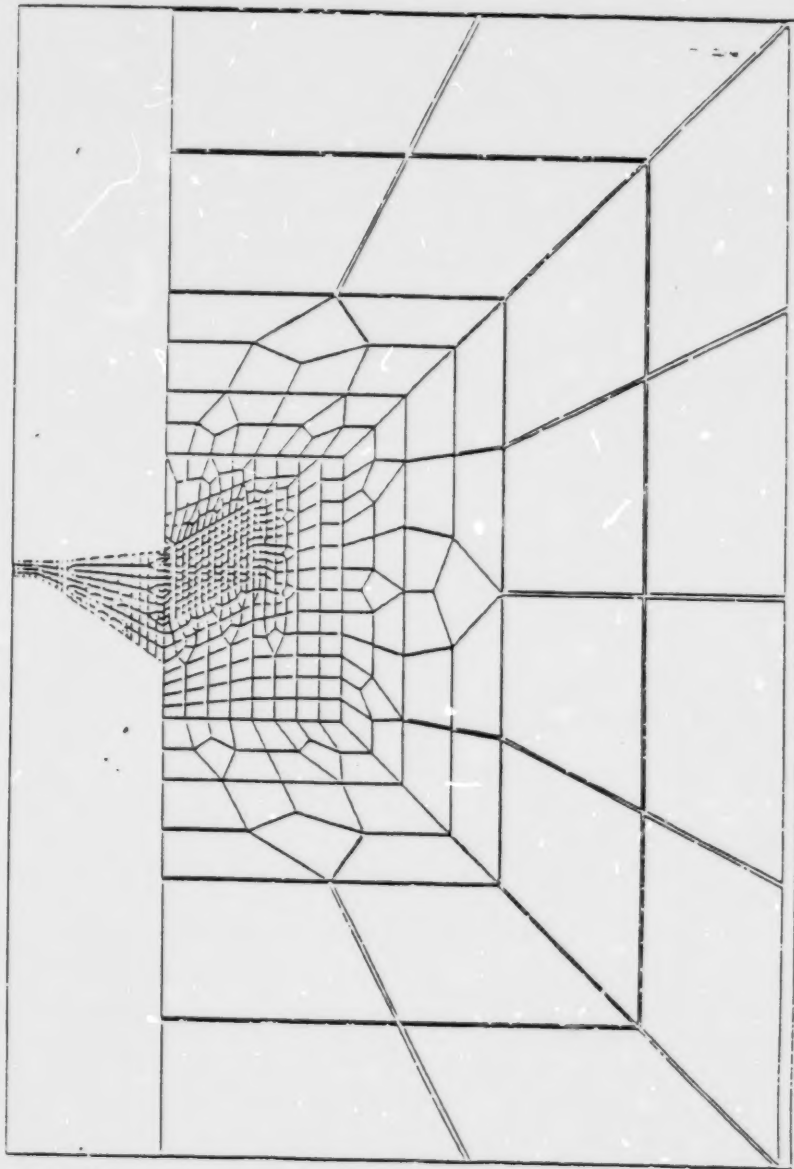


Figure B.9: FEM Analysis Concrete Gravity Dam Using 'QUAD'

Keyword ENDBC

Purpose END BOUNDARY CONDITION INPUT AND ALSO SET ELEMENT PROPERTIES

Format ENDBC

Example ENDBC

Notes

Subroutine
Various

Menu Option
Several in 5

When Necessary

Reference
44

Keyword EX

Purpose DEFINE STRESSES AROUND EXCAVATION PERIMETERS

Format EX

NLIN1

IPER1, KODEX, SXX, SYY, SXY

IPER1, KODEX, SXX, SYY, SXY

etc.

Example EX

2

1, 0, 0, 0, 0

2, 1, -10, -20, 0

Notes

1. KODEX - defining type of loading on excavation parameter
= 0 if stresses are taken from primitive stresses as defined by the PRIM keyword.
= 1 if stresses are defined by SXX, SYY, AND SXY.
2. Compressive stresses are negative.
3. If KODEX = 0, set SXX = SYY = SXY = 0 also.
4. This offers a convenient way to apply a distributed load along various boundaries. Usually used with keywords PRIM and PERI.
5. NLIN1 is the number of excavation perimeters to have stresses placed on. IPER1 is the number of the perimeter as defined by the PERI keyword.

Subroutine
INEX

Menu Option
Usually for
modelling under-
ground excavations.

When Necessary
14

Reference

Keyword GRAV

Purpose ADD GRAVITY LOAD AT SPECIFIED ELEMENTS

Format GRAV

NLIN1

IFROM, ITO

IFROM, ITO

etc.

Example GRAV

2

1, 30

1000, 1001

Notes

Subroutine
INGRAV

Menu Option
Before doing a RUN.

When Necessary
42

Reference

Keyword HEAD

Purpose READ IN USER HEADING/PROBLEM DESCRIPTION

Format HEAD
CHAR

Example HEAD

Sample Test Run, Step 1

Notes

1. CHAR is a character string holding the header description. CHAR should be characters or less in length.

Subroutine
INHEAD

Menu Option
At the start of
each new run or
new step.

When Necessary
55

Reference

Keyword HELP

Purpose GIVE THE USER HELP -- IF AVAILABLE

Format HELP

Example HELP

Notes

1. Allows you to get simple help on Quad and the keywords that are used to control it.

Subroutine
HELKEY

Menu Option
9.1

When Necessary
If you need help.

Reference
3

Keyword INIT

Purpose INITIALIZE STRESSES, DISPLACEMENTS, STRAINS AND FORCES

Format INIT

Example INIT

Notes

1. Useful for initializing stresses, etc., before a new run when it is not required to read in the full mesh geometry again.
2. If new loads are specified and the RUN keyword is issued, the Q501, Q502, Q503, and Q504 subroutines will not be run unless necessary. (This can sometimes save hours of execution time.)

Subroutine	Menu Option	When Necessary	Reference
Q102	1.2	For a new run with same geometry as previous run.	17

Keyword ISSW

Purpose DEFINE INTEGER SWITCHES (OPTIONAL)

Format ISSW

ISW, IVAL

ISW, IVAL

0,0

Example ISSW

1, 3

0,0

Notes

1. These switches are not required for normal program usage. Their purpose is to control various aspects of the Quad program. They are normally set through the program, and the user does not need set them himself.
2. The above example will display element contours every fifth element.
3. These switches are not required for normal program usage.

Subroutine
INISSW

Menu Option

When Necessary
Not really needed.

Reference
19

Keyword JOINT
Purpose INPUT JOINT PROPERTIES

Format JOINT
NLIN1
JS, CJ(JS), PHJ(JS), ALJ(S), TJ(JS), CONJ(JS), SPJ(JS), RCJ(JS), CCJ(JS), BJ(JS)
JS, CJ(JS), PHJ(JS), ALJ(JS), TJ(JS), CONJ(JS), SPJ(JS), RCJ(JS), CCJ(JS), BJ(JS)
etc.

Example JOINT
1
1, 0.01, 30, 90, 0.01, 1, 0.1, 0, 0, 0.02

Notes

JS	Joint Set Element
CJ(JS)	Cohesion for Joint
PHJ(JS)	Friction angle for JS
ALJ(JS)	Orientation (in degrees from +X direction to +Y Direction)
TJ(JS)	Tensile strenght of joint
CONJ(JS)	Continuity factor for Joints (0 to 1) 1: fully continuous 2: fully discontinuous
SRJ(JS)	Average Spacing (in metres)
RCJ(JS)	Residual Cohesion
CCJ(JS)	Continuity describing relative offset to intact rock because of the presence of joints (0.01 to 0.1)
BJ(JS)	Shear strength reductive factor

Subroutine	Menu Option	When Necessary	Reference
INJNT		Before keyword RUN.	43

Keyword LAST

Purpose LAST KEYWORD AVAILABLE SEE GETKEY

Format LAST

Example LAST

Notes

1. This option is not available yet.

Subroutine

Menu Option

When Necessary
Not available yet.

Reference
64

Keyword LIN
Purpose SET A LINEAR RUN

Format LIN

Example LIN

Notes

1. This is the default if LIN or NLIN have not been specified.
2. Has the same effect as setting integer switch ISSW(4) = 2.
3. Must be before the RUN keyword and preferably before the OUT1 keyword.
4. Using LIN will force a linear run even if material properties are defined as non-linear.

Subroutine
INNON

Menu Option
4.1

When Necessary
Input

Reference
13

Keyword LINBC

Purpose SPECIFY LINE LOAD BC'S, NODE BY NODE

Format LINBC

Example LINBC

Notes

1. This option is not functional yet.

Subroutine

Menu Option

When Necessary
Not available yet.

Reference
37

Keyword MATEL
Purpose SPECIFY MATERIAL TYPE FOR EACH ELEMENT

Format MATEL
NLIN1
IFROM, ITO, K

Example MATEL

4
1, 2, 1
3, 3, 2
4, 10, 3
11, 11, 4

Notes

1. IFROM and ITO are the starting and ending elements in a group of elements to have the material property type K.
2. All elements should have an element type defined.
3. Elements can be defined in any order.

Subroutine
INMATE

Menu Option
Input (Essential)

When Necessary
35

Reference

Keyword MATP

Purpose START READING MATERIAL PROPERTIES FOR A SUBREGION

Format MATP

NLIN3

CHAR

K,UNITW,E,V,E2,V2,G2,ANISO

MTYP,P1,P2,P3,P4,P5,MPEN

CHAR

K,UNITW, etc.

Example MATP

2

Hard rock, linear elastic, Pen 3

1, -0.026, 100000.0, 0.2, 0, 0, 0, 0

0, 0, 0, 0, 0, 0, 3

Soft rock, non associated Mohr Coulomb, Pen 4

2, -0.024, 10000.0, 0.25, 0, 0, 0, 0

3, 1, 6, 35, 10, 0, 4

Notes

1. Two subregions are defined above, the second being a softer rock with tensile strength = 1, cohesion = 6, friction angle = 35, and dilation angle = 10.
2. UNITW is the unit weight of the rock, and is in MN/m^3 . The negative sign in front means that the weight is in the sense of decreasing Y axis values (to be given a negative sign if Y+ points up).
3. Young's Modulus (E) is in MPa.
4. E2, V2, and G2 are the second Young's modulus, Poisson's ratio, and shear modulus, respectively for anisotropic material.
5. ANISO is the default anisotropic angle, in degrees measures from +X to +Y. Note: E2,V2,G2 = ANISO=0 for isotropic material.
6. MTYP is a material type code. Further details are available in later notes.
7. See separate notes for further details on non-linear material codes and properties.

Subroutine

INMATP

Menu Option

Input (Essential)

When Necessary

11

Reference

Keyword MENU

Purpose ENTER THE INTERACTIVE MENU

Format MENU

Example MENU

Notes

1. Useful for doing post-processing on your run. It allows you to interactively run Quad and make changes, make plots, etc., without having to change you original control file.

Subroutine
MENU

Menu Option
For interactive
control of Quad.

When Necessary
2

Reference

Keyword MESH

Purpose PREPARE MESH FOR PLOTTING

Format MESH

Example MESH

Notes

1. The user is interactively asked which nodes, elements and pens are to be prepared for the mesh plot, as well as the shrinkage factor for elements. (Elements may be plotted slightly smaller so that each element may be viewed separately from it's neighbours.)
2. Plot file containing the mesh is QUAD.PM.
Plot file containing node numbers is QUAD.PN.
Plot file containing element numbers is QUAD.PE.

Subroutine
Q302

Menu Option
3.2 or 7.1

When Necessary
For mesh plots.

Reference
50

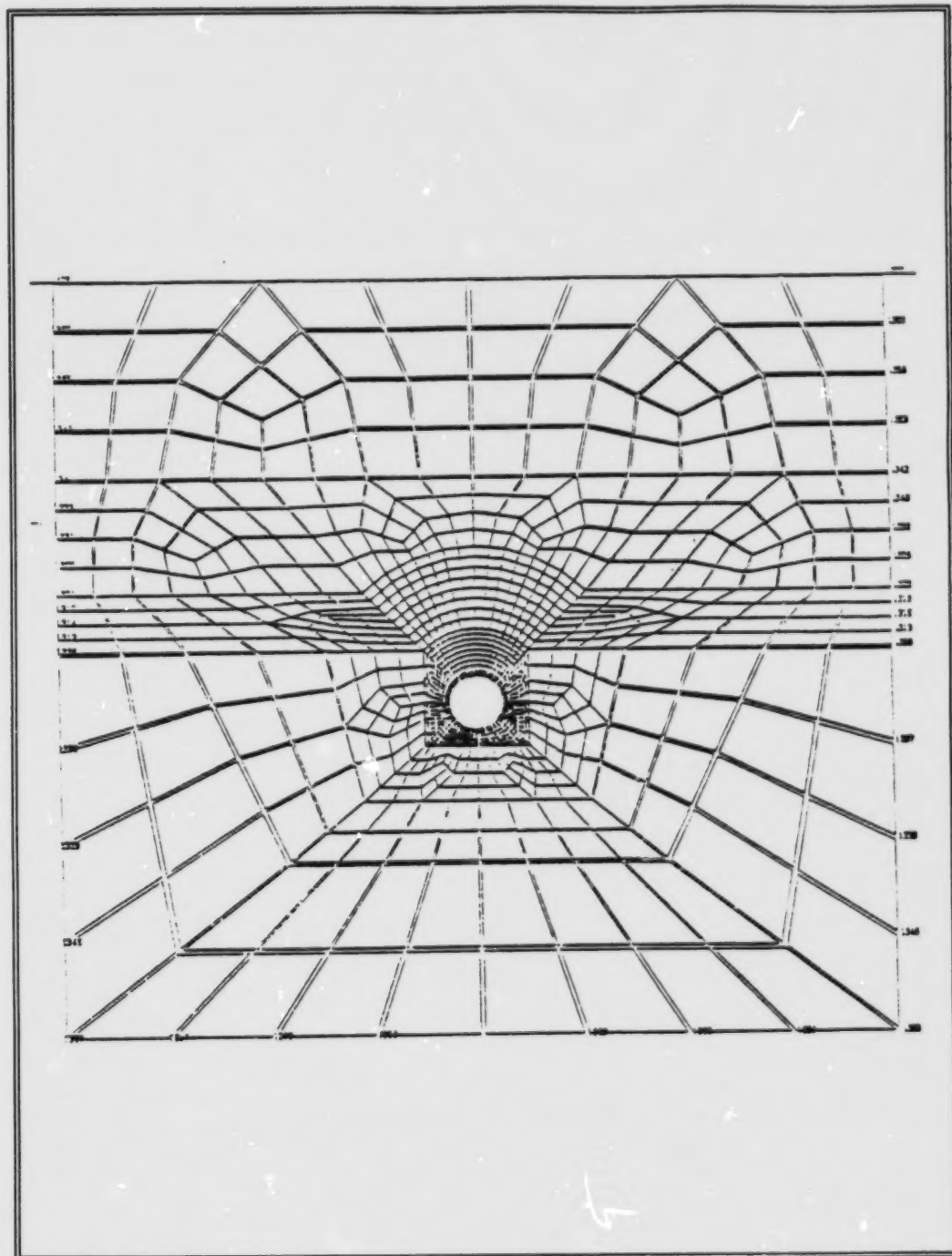


Figure B.10: Buried Pipe Analysis

Keyword NLIN
Purpose SET A NON-LINEAR RUN

Format NLIN

Example NLIN

Notes

1. Has the same effect as setting integer switch ISSW(4) = 3.
2. Must be used before the RUN keyword and preferably before the OUT1 keyword.

Subroutine	Menu Option	When Necessary	Reference
INNON	4.2	For non-linear run.	15

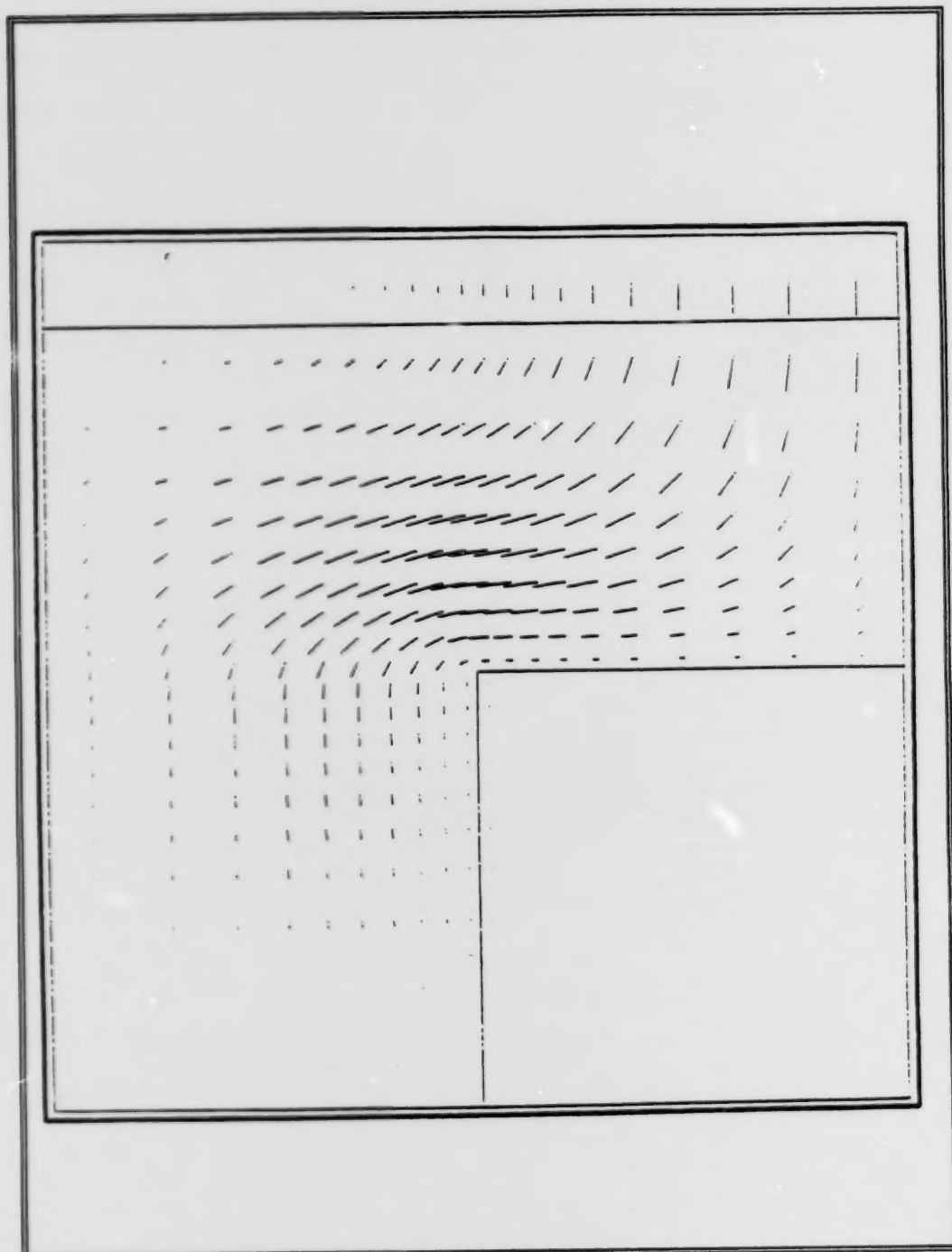


Figure B.11: Non-linear Test Problem Flow Vectors for Compressible Flow/Distorsion

Keyword NODES

Purpose START READING NODES

Format NODES

NLIN1

N,X,Y

N,X,Y

ETC.

Example NODES

4

1,0,0

2,20,0

3,20,30

4,0,30

NODES

1000

61,31.68,41.2

OR62,41.44,48.8

0,0,0

Notes

1. Input of nodal coordinates are terminated either when the number NLIN1 of nodal coordinates have been read in or when a node number 0 with coordinates (0,0) is read in.
2. Nodes may be in any order and not all nodes need to be defined.
3. Node numbering is important. This is so that nodal bandwidth may be reasonably minimal.
4. Nodal coordinates should be in feet or meters, meters being preferred.

Subroutine
INNODE

Menu Option
Input

When Necessary
9

Reference

Keyword NODP

Purpose PREPARE NODAL RESULTS FOR PLOTTING

Format NODP

Example NODP

Notes

1. Plot options are interactive.
2. Options include total or incremental displacements or forces.
3. Plot file containing information on displacements or forces is QUAD.PN.
Plot file containing stress vectors is QUAD.PS.
Plot file containing displacement vectors is QUAD.PV.

Subroutine
Q704

Menu Option
7.4

When Necessary
As required

Reference
59

Table B.2: Choices for Values to PLOT Nodes

Choice #	Description of choice
1	For horizontal total displacements
2	For vertical total displacements
3	For horizontal incremental displacements
4	For vertical incremental displacements
5	For total horizontal forces
6	For total vertical forces
7	For incremental horizontal forces
8	For incremental vertical forces

Table B.3: Choices for Values to Plot at Elements

Choice #	Description of choice
1	For horizontal displacements
2	For vertical displacements
3	For Max stresses
4	For Min stresses
5	For Max shear stresses
6	For vertical stresses
7	For horizontal stresses
8	For maximum strains
9	For minimum strains
10	For extension strains
11	For Hoek's rock mass failure criterion (FOS)
12	For Hoek's excess stresses
13	For volumetric strains
14	For Mohr Coulomb excess stress
15	For stresses and displacement vectors only

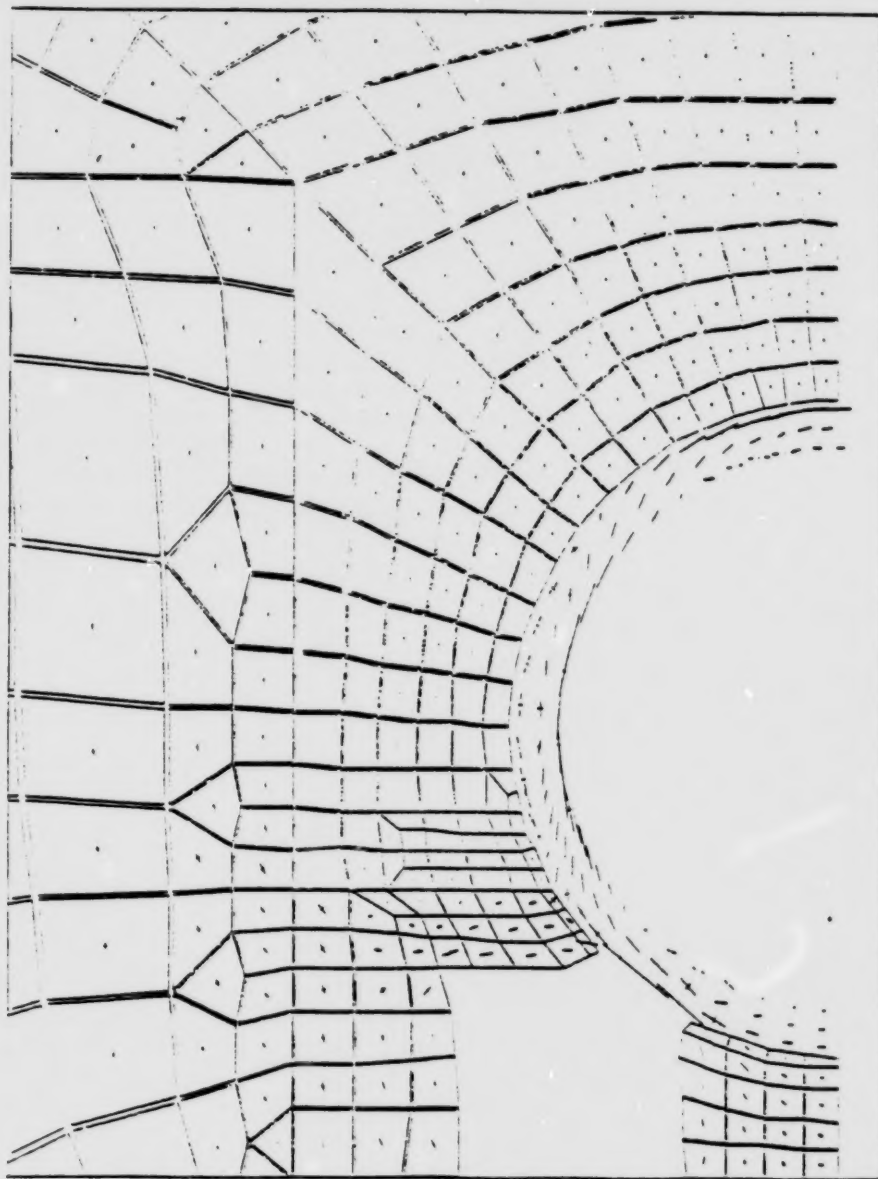


Figure B.12: Defective Haunching Analysis

Keyword NONI
Purpose INPUT NON-LINEAR ITERATION PARAMETERS

Format NONI
NITER, OMEGA, DEL

Example NONI
500, 1.85, 0.01

Notes

Subroutine
INNONI

Menu Option

When Necessary
After NLIN keyword.

Reference
56

Keyword OUT1

Purpose PRINT OUT HEADER INFORMATION

Format OUT1

Example OUT1

Notes

1. Prints out number of nodes, elements, boundary conditions, etc., and primitive stress conditions, heading and type of run.
2. May be used anywhere, but is useful just before the RUN keyword.

Subroutine
HEADER

Menu Option
6.1

When Necessary
As required.

Reference
22

Keyword OUT2

Purpose PRINT NODE/ELEMENT GEOMETRY FOR EASY RE-INPUT

Format OUT2

Example OUT2

Notes

1. Prints out all nodes in the format

N, X, Y

2. Prints out all elements in the format

I, N1, N2, N3, N4

3. Useful after creating a mesh with the digitizer options, or after doubling up a mesh. Prints to an ASCII file TEMP.LST and allows easy editing for further use, or as a back up of the geometry of a current run.

Subroutine
Q301

Menu Option
6.7

When Necessary
As required.

Reference
23

Keyword OUT3
Purpose PRINT SELECTED ELEMENT GEOMETRY

Format OUT3

Example OUT3

Notes

1. The following information is printed out for this selection.

ELT	Element number
NODES	Nodes that make up a given element
COORDINATES	(X,Y) coordinate of the center of the element
AREA	Area of the element
PRIMITIVE	
STRESSES	Primitive stresses present at the start of the run in the X, Y, and XY shear directions.
2. Useful in checking starting stress values of a run.

Subroutine
Q203

Menu Option
6.2

When Necessary
As required.

Reference
24

Keyword OUT4
Purpose PRINT OUT MATERIAL PROPERTIES

Format OUT4

Example OUT4

Notes

1. Prints out the following information on material properties:
 - Subregion Number
 - Description
 - Young's Modulus
 - Poisson's Ratio
 - Density
 - Pen number
 - Material Type (if non-linear run)
 - Aniso / Isotropic (for non-linear run)

Subroutine
OUTMAT

Menu Option
6.3

When Necessary
As required.

Reference
25

Keyword OUT5

Purpose PRINT OUT ELEMENT SOLUTIONS

Format OUT5

Example OUT5

Notes

1. Useful as a record of displacements, stresses and strains that occur at the elements after a run has been completed.
2. The following information is printed by this option.

ELT	Element number.
COORDINATES	X and Y coordinate of the center of the element.
DISPLACEMENTS	U and V displacements of the center of the element. Displacements are in feet or meters, whatever units you used as input to Quad.
STRAINS	Strains in the X, Y, and XY shear directions.
STRESSES	Stresses in the X, Y, and XY shear directions. Stresses are in MPa.
PRINCIPAL STRESSES	Principal stresses σ_1 and σ_2 and their directions θ_1 and θ_2 . Stresses are in MPa, and direction angles are in degrees.
3. If a non-linear run is performed, then stresses will only be available at element centroids.

Subroutine
Q701

Menu Option
6.5

When Necessary
As required.

Reference
26

Keyword OUT6

Purpose PRINT OUT NODAL SOLUTIONS

Format OUT6

Example OUT6

Notes

1. Useful as a record of displacements and forces at nodes after a run has been performed.
2. The following information is printed by this option.
NODE Node number
COORDINATES X and Y coordinates of the node
NODAL FORCES Forces on the node in the X and Y directions.
DISPLACEMENTS U and V displacements of the nodes. The units are feet or meters, whichever was used on input of the nodes.
EXPONENT FORMAT As displacements, but in exponent notation.

Subroutine
Q702

Menu Option
6.4

When Necessary
As required.

Reference
27

Keyword OUT7

Purpose PRINT OUT PERIMETER INFORMATION

Format OUT7

Example OUT7

Notes

1. Useful as a record of perimeters used.
2. The format of the output is as follows.
The number of perimeters that information will be printed on.

For each perimeter, the following is printed.

- The perimeter number, and how many nodes make it up.
- Description of the perimeter.
- Nodes that are in a particular perimeter.

Subroutine
OUTPER

Menu Option
6.6

When Necessary
As required.

Reference
28

Keyword OUT8

Purpose PRINT OUT ELEMENT/SUBREGION DEFINITIONS

Format OUT8

Example OUT8

Notes

1. Useful as a record of which elements have what material property.
2. The format of the output is as follows.
FROM ELEMENT The starting element of a series that will have the element properties that follow.

DESCRIPTION
OF MATERIAL Description of the material type as defined with the MATP keyword.

Young's Modulus

Poisson's Ratio

SUBREGION NUMBER

Subroutine
OUT8

Menu Option
6.8

When Necessary
As required.

Reference
29

Keyword OUT9
Purpose

Format OUT9

Example OUT9

Notes

1. This option is a spare option. It is there for future versions use.

Subroutine

Menu Option

When Necessary
Not used as of yet.

Reference
30

Keyword PAIN
Purpose PLAIN STRAIN ANALYSIS

Format PAIN

Example PAIN

Notes

Subroutine
QUADKEY

Menu Option
4.3

When Necessary
Input

Reference
39

Keyword PERI

Purpose READ SEQUENCES OF NODES DEFINING PERIMETERS

Format PERI

NGROUP

IPERI, NPERI

CHAR

N1, N2, N3, ... , NN

Example PERI

2

1, 5

Test Perimeter 1, 5 nodes, open.

5, 10, 15, 20, 25

2, 6

Test Perimeter 2, 6 nodes, closed.

5, 10, 15, 20, 25, 5

Notes

1. Perimeters are usually defined for plotting purposes or to define an excavation perimeter.
2. Maximum number of points in a perimeter is 1000.
3. NGROUP is the number of perimeters that follow. IPERI is the number of the perimeter being defined, and NPERI is the number of nodes that are used to define the perimeter.
4. Perimeters may be open or closed. It is closed if the first and last nodes in the list are the same, and open if they are not.
5. The form of N1, N2, ... , NN is free and can extend over one, two, or more lines if needed.

Subroutine
INPERI

Menu Option
Working with
perimeters.

When Necessary
7

Reference

Keyword PERP

Purpose PREPARE PERIMETERS FOR PLOTTING

Format PERP

Example PERP

Notes

1. Useful for showing geological zones, excavation surfaces or load lines.
2. Any perimeter read in with the PERI keyword may be used.
3. Results ready for plotting are stored in the file QUAD.PP.

Subroutine
Q304

Menu Option
3.4

When Necessary
As required.

Reference
60

Keyword PESS

Purpose PLAIN STRESS ANALYSIS

Format PESS

Example PESS

Notes

Subroutine
QUADKEY

Menu Option
4.4

When Necessary
Input

Reference
40

Keyword PLBC

Purpose PREPARE BOUNDARY CONDITIONS FOR PLOTTING

Format PLBC

Example PLBC

Notes

1. Useful for plotting out boundary condition codes of nodes as a check of their values.
2. Values of the codes are stored in QUAD.PN.

Subroutine
Q303

Menu Option
3.3

When Necessary
As required.

Reference
51

Keyword PRIM

Purpose READ IN PRIMITIVE STRESS CONDITIONS

Format PRIM

PXX, PYY, PXY, DXX, DYY, DXY

or

PRIM

PXX, PYY, PXY

DXX, DYY, DXY

Example PRIM

0, 0, 0

0.054, 0.027, 0

Notes

1. Stresses are in MPa. PXX, PYY, and PXY are constant primitive stresses, and DXX, DYY, and DXY are depth dependant stresses.
2. In Quad, negative stresses are compressive; positive stresses indicate tension.
3. If your run uses only positive Y values, values of stresses should be negative.
4. The above example will give horizontal compressive stress of -54 MPa at a 'depth' of 1000m when Y = -1000. The vertical compressive strength would be -27 MPa.

Subroutine
INPRIM

Menu Option
Input

When Necessary
21

Reference

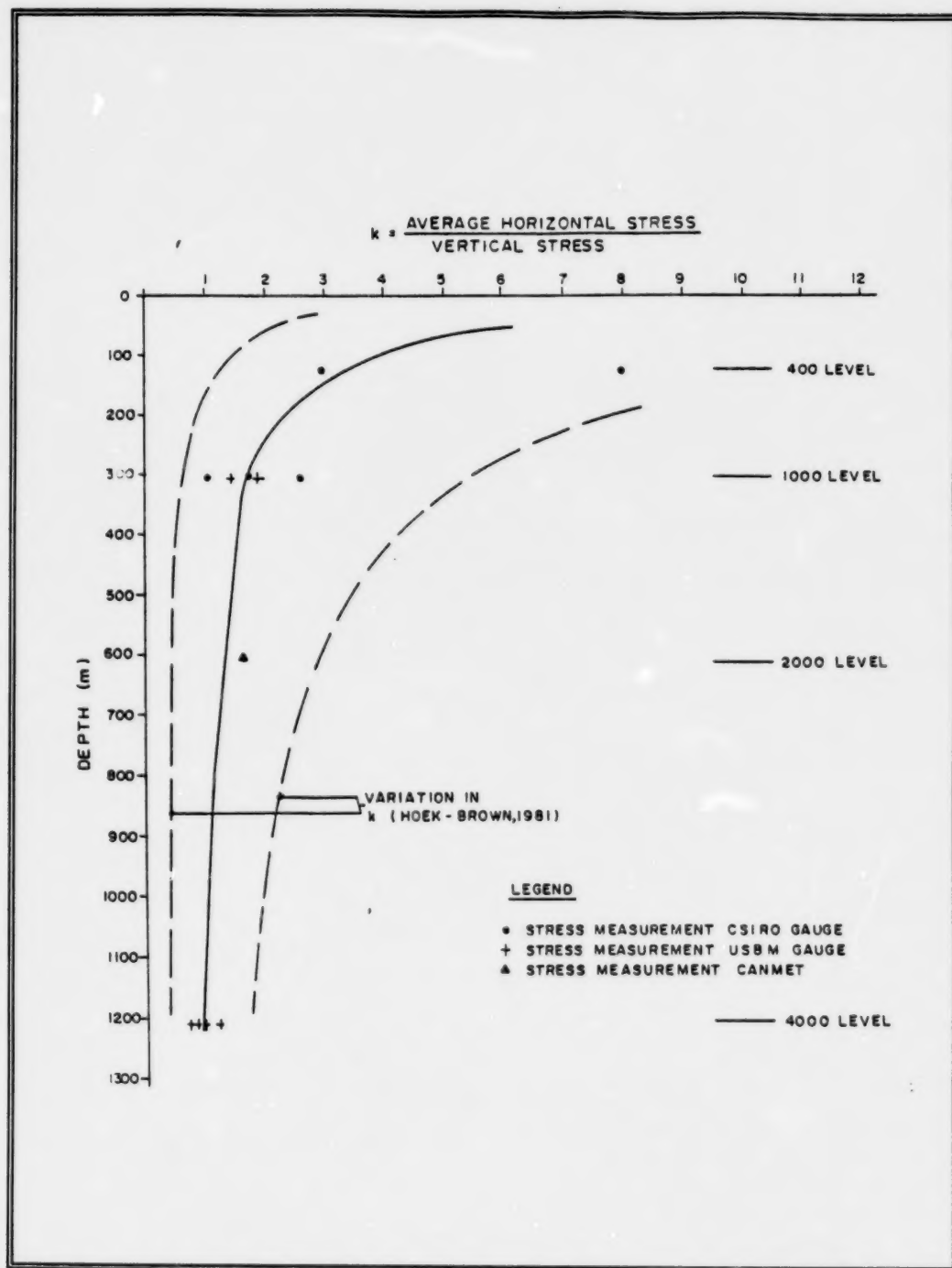


Figure B.13: Estimated K-Ratio Gradient

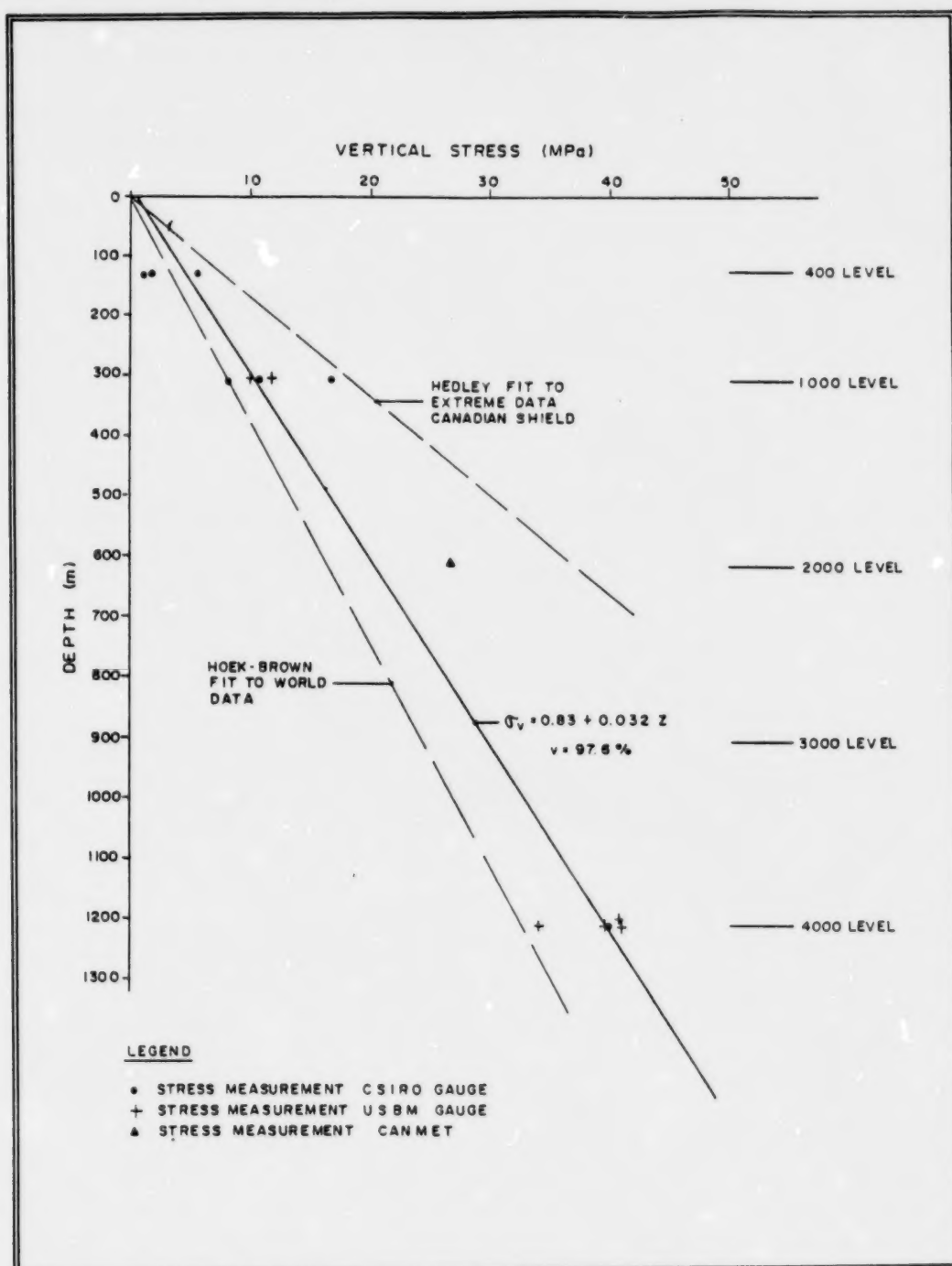


Figure B.14: Estimated Vertical Stress Gradient

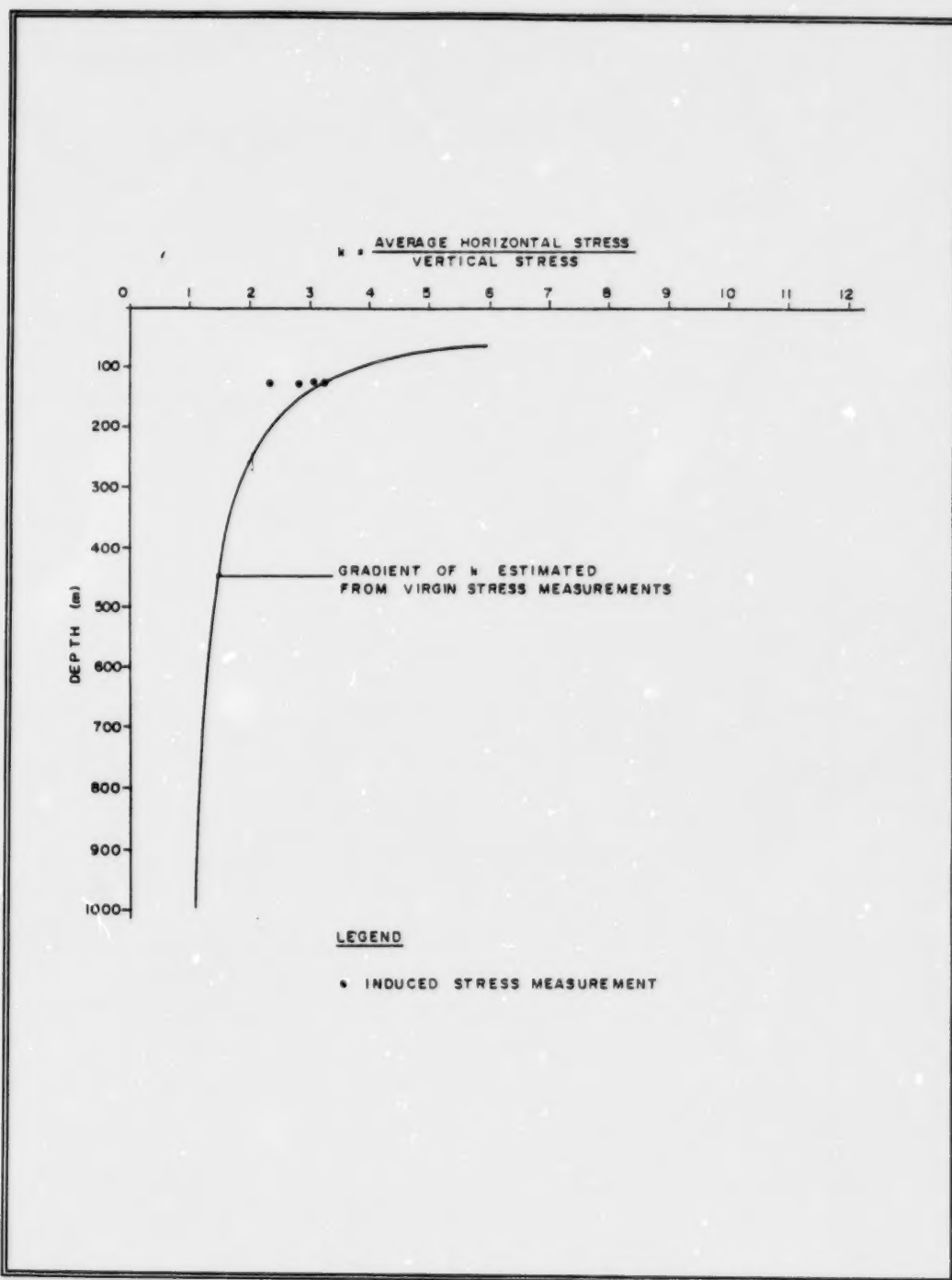


Figure B.15: Comparison Between Estimated Virgin K-Ratio and induced K-Ration

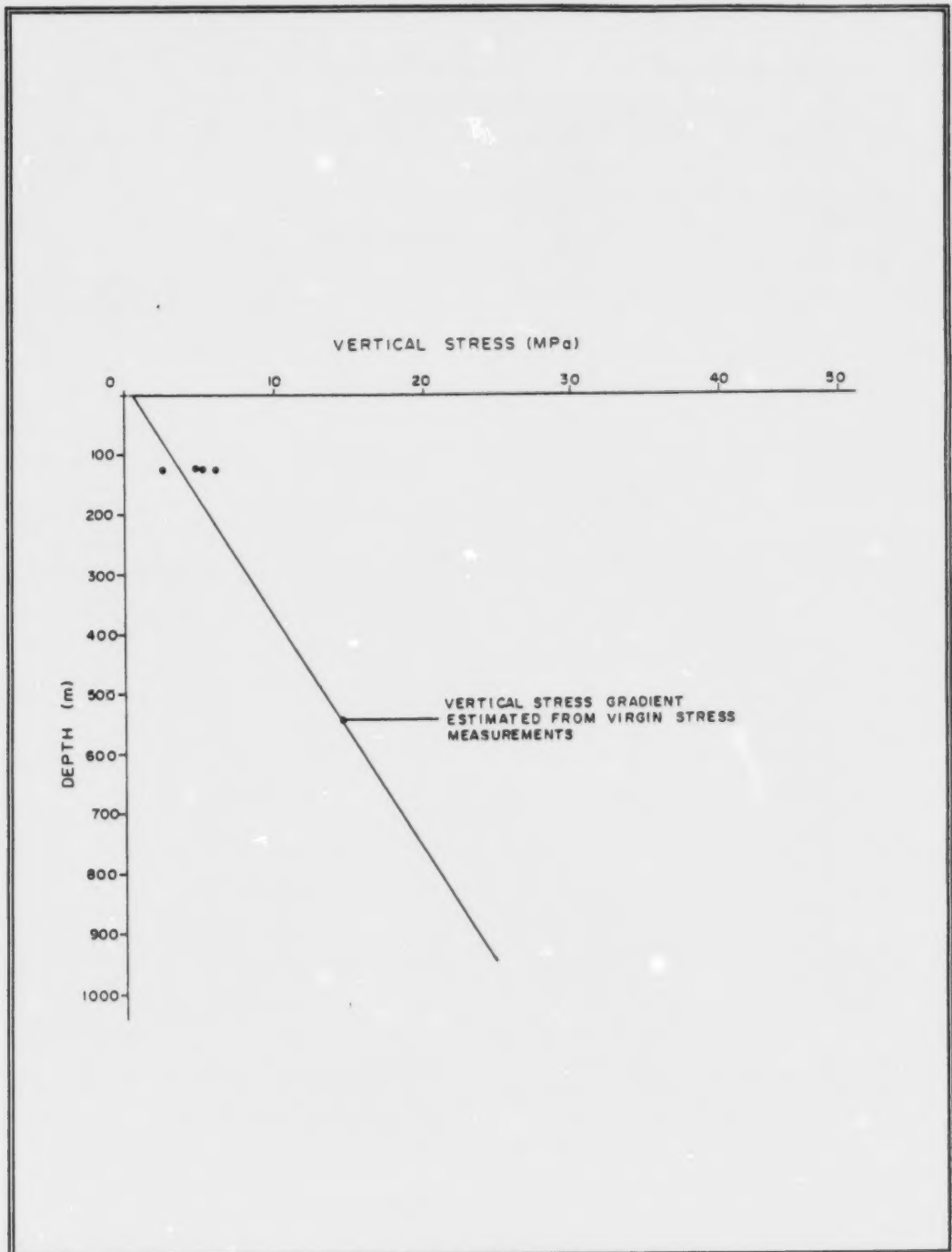


Figure B.16: Comparison Between Estimated Vertical Virgin Stress and Induced Stress

Keyword RUN

Purpose START EXECUTING NUMBER CRUNCHING FOR THE CURRENT STEP

Format RUN

Example RUN

Notes

1. RUN performs the following routines:

Calculate element stiffness (Q501)

Calculates gravity and boundary loads (Q501a)

Calculates profile of equations (Q502)

Assembles global stiffness matrix (Q503)

Eliminates global stiffness matrix (Q504)

Back substitutes for applied forces (Q505)

Updates element stresses (Q506)

Updates nodal forces (Q507)

Finds excess stresses and forces for non-linear run (Q508)

Continues with Q505 if necessary for a non-linear run

Subroutine	Menu Option	When Necessary	Reference
Q5005.9	For any step after input.	8	

Keyword SKIP

Purpose SELECT ELEMENTS TO BE SKIPPED IN POST PROCESSING

Format SKIP

NLIN1

IFROM, ITO, IVAL

IFROM, ITO, IVAL

etc.

Example SKIP

2

1, 10, 1

11, 15, 0

Notes

1. IFROM and ITO are the first and last elements in a group of elements to get a value IVAL. IVAL holds the skipping value. IVAL = 1 means that these elements are not to be included in printouts. IVAL = 0 means that they are included in printouts.

Subroutine
INSKIP

Menu Option

When Necessary
To reduce output.

Reference
49

Keyword SSW

Purpose DEFINE REAL SWITCHES

Format ISW

ISW, IVAL

ISW, IVAL

0,0

Example SSW

1, 1.5

0,0

Notes

1. These switches are not required for normal program usage. Their purpose is to control various aspects of the Quad program. They are normally set through the program, and the user does not need set them himself.

Subroutine
INSSW

Menu Option

When Necessary
Not really needed.

Reference
20

Keyword START

Purpose START A TOTALLY NEW RUN -- INITIALIZE EVERYTHING

Format START

Example START

Notes

1. Used to start a new run of Quad by initializing all files and arrays.
2. This option need only be run when performing a new analysis. If you are only changing stresses, material properties, etc., and leaving the geometry of the run the same, use the INIT command instead.

Subroutine
Q101

Menu Option
1.1

When Necessary
For an entirely
new run.

Reference
4

Keyword STEP

Purpose READ IN MULTIPLE STEP INFORMATION

Format STEP

Example STEP

Notes

1. Usually followed by keywords MATP or MATE and/or BC and/or RUN.
2. Material properties, boundary conditions or element types are usually changed after a STEP keyword and before another RUN keyword.
3. Incremental forces and displacements are initialized, but total forces and displacements are not altered.

Subroutine
STEP

Menu Option

When Necessary
For multiple mining
step analysis.

Reference
16

Keyword STIFF

Purpose UPDATE STIFFNESS ARRAY (AFTER CHANGES TO MATERIAL TYPES)

Format STIFF

Example STIFF

Notes

Subroutine
Several

Menu Option
Several in 5

When Necessary
To update stiffness
without running all
number crunching.

Reference
5

Keyword STOP
Purpose STOP EXECUTION

Format STOP

Example STOP

Notes

1. Used to stop a run of Quad controlled by a keyword file and exit the program.

Subroutine
QUADKEY

Menu Option
0

When Necessary
To exit Quad

Reference
1

Keyword TELT
Purpose TRANSFORM ELEMENTS
Format TELT

Example TELT

Notes

- 1. This option is not available yet.

Subroutine	Menu Option	When Necessary	Reference
	Not available yet.	34	

Table B.4: Non-linear Material Types and Output Parameters

Type Code	Description	Parameters Outputed
1	No tension material	Tensile strength
2	Mohr Coulomb material	Tensile strength, cohesion and angle of friction of joint set
3	Non-ass Mohr Coulomb	Tensile strenght, cohesion, angle of friction, and dilatancy factor of joint set
4	Special air elements	nothing
5	Total closure elements	nothing
6	Hoek's failure criterion	nothing
7	Backfill (Quadratic)	Coefficients of quadratic equation, A, B and C
8	Backfill (Cubic)	Coefficients of cubic equation, A, B and C
10	Jointed material	Tensile strength, cohesion, angle of friction, and dilatancy factor of joint set
12	Jointed material	Tensile strenght, cohesion, angle of friction, and dilatancy factor of joint set

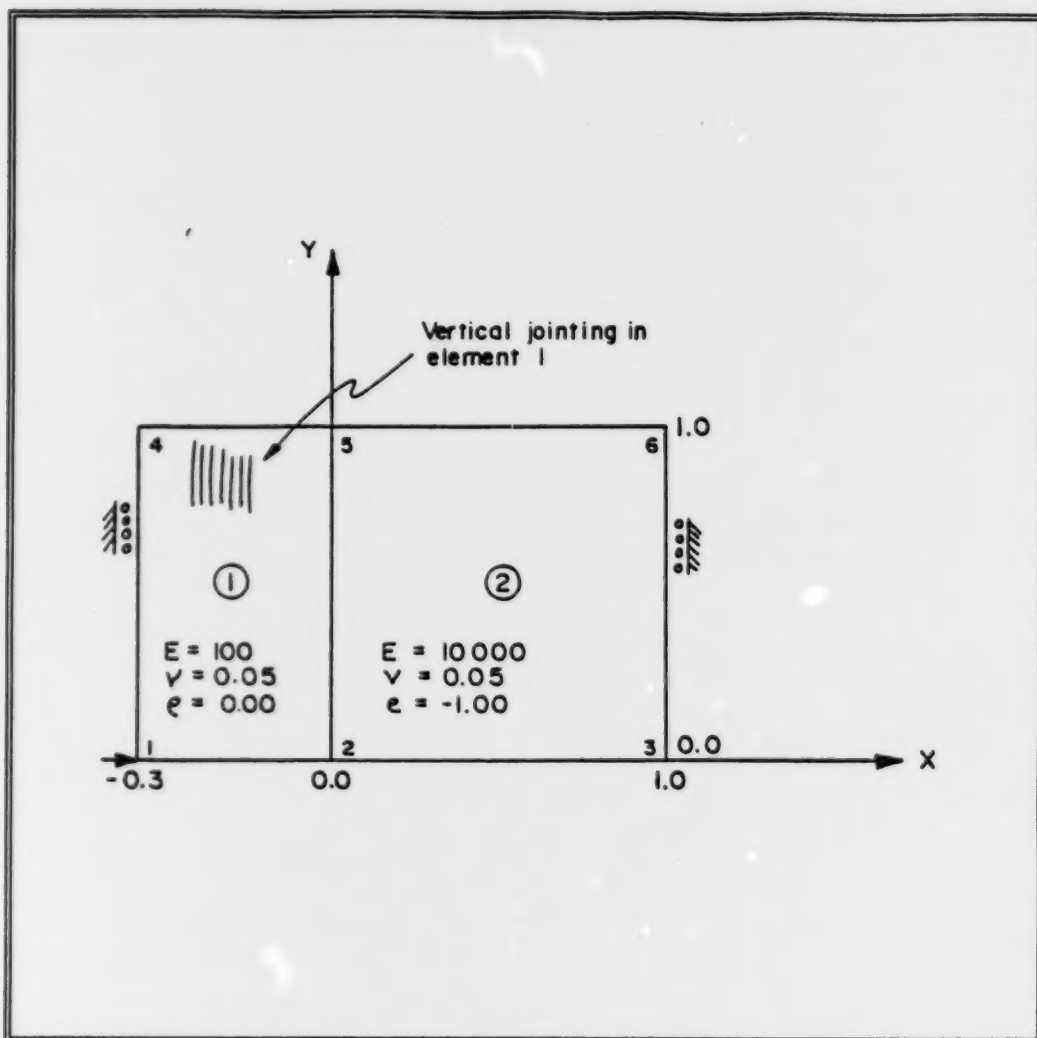


Figure B.17: Geometry and Material Properties for Joint Example

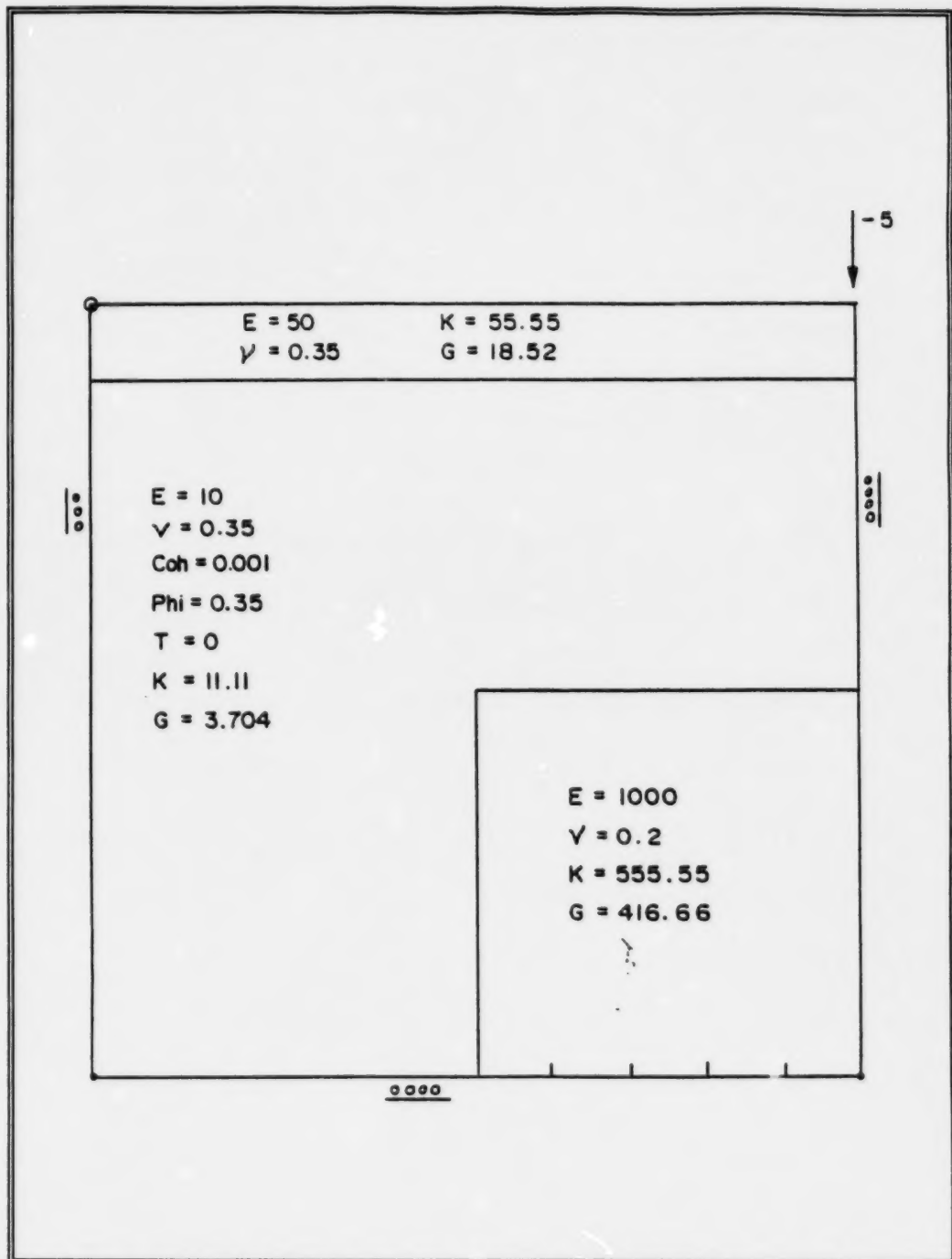


Figure B.18: Geometry and Material Properties for Non-linear Test Problem

Keyword TNOD
Purpose TRANSFORM NODES

Format TNOD

Example TNOD

Notes

1. This option is not available at the moment.

Subroutine

Menu Option
Not available yet.

When Necessary
33

Reference

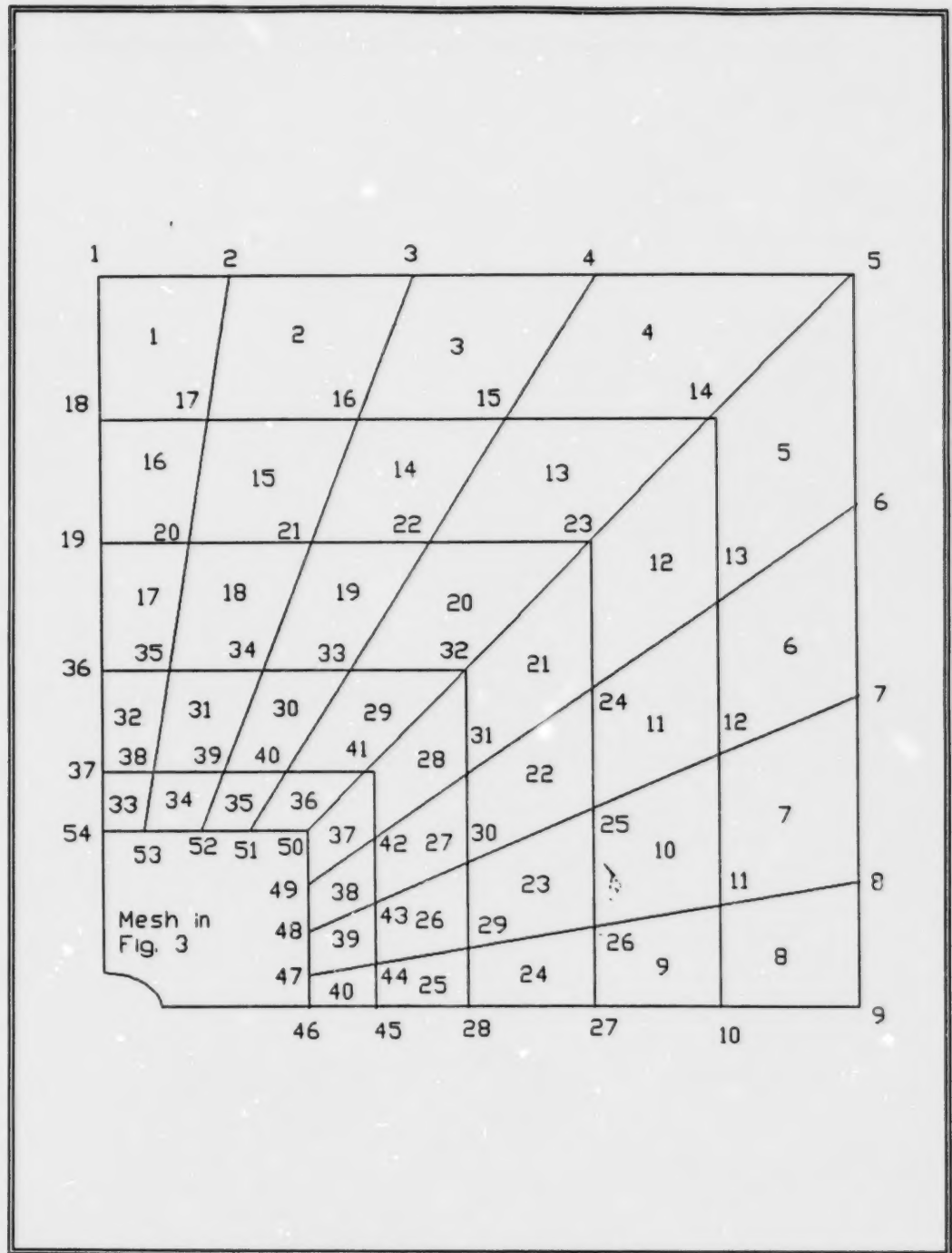


Figure B.19: Outer Mesh for Circular Tunnel (for Inner Mesh See fig. 3)

Keyword VIRG

Purpose ALLOCATE PRIMITIVE STRESS CONDITIONS TO SELECTED ELEMENTS

Format VIRG
NLIN1
IFROM, ITO
IFROM, ITO
etc.

Example VIRG

1
1, 560

Notes

1. The above example sets primitive stresses as defined by the PRIM keyword to elements 1 to 560.
2. NLIN1 is the number of IFROM, ITO element pairs of information to follow.

Subroutine
INVIRG

Menu Option
Before doing a RUN.

When Necessary
47

Reference

Keyword ZBC

Purpose INITIALIZE ALL BOUNDARY CONDITIONS TO ZERO

Format ZBC

Example ZBC

Notes

Subroutine
ZBC

Menu Option
4.1

When Necessary
To initialize all
boundary conditions.

Reference
38



APPENDIX C

Example

TABLES OF CONTENTS

C-1	DATA FILE	C-1
C-2	RESULTS	C-8

LIST OF FIGURES

C.1	Non-linear Run, Original Mesh	C-28
C.2	Non-linear Run, Nodes	C-29
C.3	Non-linear Run, Elements	C-30
C.4	Non-linear Run, Stresses (bold lines are tensions)	C-31
C.5	Non-linear Run, Displacement	C-32
C.6	Non-linear Run, Deformed Mesh	C-33

C-1 DATA FILE

START

NODES

121

1,	0.0000,	0.0000
2,	1.0000,	0.0000
3,	2.0000,	0.0000
4,	3.0000,	0.0000
5,	4.0000,	0.0000
6,	5.0000,	0.0000
7,	6.0000,	0.0000
8,	7.0000,	0.0000
9,	8.0000,	0.0000
10,	9.0000,	0.0000
11,	10.0000,	0.0000
12,	0.0000,	1.0000
13,	1.0000,	1.0000
14,	2.0000,	1.0000
15,	3.0000,	1.0000
16,	4.0000,	1.0000
17,	5.0000,	1.0000
18,	6.0000,	1.0000
19,	7.0000,	1.0000
20,	8.0000,	1.0000
21,	9.0000,	1.0000
22,	10.0000,	1.0000
23,	0.0000,	2.0000
24,	1.0000,	2.0000
25,	2.0000,	2.0000
26,	3.0000,	2.0000
27,	4.0000,	2.0000
28,	5.0000,	2.0000
29,	6.0000,	2.0000
30,	7.0000,	2.0000
31,	8.0000,	2.0000
32,	9.0000,	2.0000
33,	10.0000,	2.0000
34,	0.0000,	3.0000
35,	1.0000,	3.0000
36,	2.0000,	3.0000
37,	3.0000,	3.0000
38,	4.0000,	3.0000
39,	5.0000,	3.0000
40,	6.0000,	3.0000
41,	7.0000,	3.0000

42,	8.0000,	3.0000
43,	9.0000,	3.0000
44,	10.0000,	3.0000
45,	0.0000,	4.0000
46,	1.0000,	4.0000
47,	2.0000,	4.0000
48,	3.0000,	4.0000
49,	4.0000,	4.0000
50,	5.0000,	4.0000
51,	6.0000,	4.0000
52,	7.0000,	4.0000
53,	8.0000,	4.0000
54,	9.0000,	4.0000
55,	10.0000,	4.0000
56,	0.0000,	5.0000
57,	1.0000,	5.0000
58,	2.0000,	5.0000
59,	3.0000,	5.0000
60,	4.0000,	5.0000
61,	5.0000,	5.0000
62,	6.0000,	5.0000
63,	7.0000,	5.0000
64,	8.0000,	5.0000
65,	9.0000,	5.0000
66,	10.0000,	5.0000
67,	0.0000,	6.0000
68,	1.0000,	6.0000
69,	2.0000,	6.0000
70,	3.0000,	6.0000
71,	4.0000,	6.0000
72,	5.0000,	6.0000
73,	6.0000,	6.0000
74,	7.0000,	6.0000
75,	8.0000,	6.0000
76,	9.0000,	6.0000
77,	10.0000,	6.0000
78,	0.0000,	7.0000
79,	1.0000,	7.0000
80,	2.0000,	7.0000
81,	3.0000,	7.0000
82,	4.0000,	7.0000
83,	5.0000,	7.0000
84,	6.0000,	7.0000
85,	7.0000,	7.0000
86,	8.0000,	7.0000
87,	9.0000,	7.0000

88,	10.0000,	7.0000
89,	0.0000,	8.0000
90,	1.0000,	8.0000
91,	2.0000,	8.0000
92,	3.0000,	8.0000
93,	4.0000,	8.0000
94,	5.0000,	8.0000
95,	6.0000,	8.0000
96,	7.0000,	8.0000
97,	8.0000,	8.0000
98,	9.0000,	8.0000
99,	10.0000,	8.0000
100,	0.0000,	9.0000
101,	1.0000,	9.0000
102,	2.0000,	9.0000
103,	3.0000,	9.0000
104,	4.0000,	9.0000
105,	5.0000,	9.0000
106,	6.0000,	9.0000
107,	7.0000,	9.0000
108,	8.0000,	9.0000
109,	9.0000,	9.0000
110,	10.0000,	9.0000
111,	0.0000,	10.0000
112,	1.0000,	10.0000
113,	2.0000,	10.0000
114,	3.0000,	10.0000
115,	4.0000,	10.0000
116,	5.0000,	10.0000
117,	6.0000,	10.0000
118,	7.0000,	10.0000
119,	8.0000,	10.0000
120,	9.0000,	10.0000
121,	10.0000,	10.0000

ELTS

100

1,	1,	2,	13,	12
2,	2,	3,	14,	13
3,	3,	4,	15,	14
4,	4,	5,	16,	15
5,	5,	6,	17,	16
6,	6,	7,	18,	17
7,	7,	8,	19,	18
8,	8,	9,	20,	19
9,	9,	10,	21,	20
10,	10,	11,	22,	21

11,	12,	13,	24,	23
12,	13,	14,	25,	24
13,	14,	15,	26,	25
14,	15,	16,	27,	26
15,	16,	17,	28,	27
16,	17,	18,	29,	28
17,	18,	19,	30,	29
18,	19,	20,	31,	30
19,	20,	21,	32,	31
20,	21,	22,	33,	32
21,	23,	24,	35,	34
22,	24,	25,	36,	35
23,	25,	26,	37,	36
24,	26,	27,	38,	37
25,	27,	28,	39,	38
26,	28,	29,	40,	39
27,	29,	30,	41,	40
28,	30,	31,	42,	41
29,	31,	32,	43,	42
30,	32,	33,	44,	43
31,	34,	35,	46,	45
32,	35,	36,	47,	46
33,	36,	37,	48,	47
34,	37,	38,	49,	48
35,	38,	39,	50,	49
36,	39,	40,	51,	50
37,	40,	41,	52,	51
38,	41,	42,	53,	52
39,	42,	43,	54,	53
40,	43,	44,	55,	54
41,	45,	46,	57,	56
42,	46,	47,	58,	57
43,	47,	48,	59,	58
44,	48,	49,	60,	59
45,	49,	50,	61,	60
46,	50,	51,	62,	61
47,	51,	52,	63,	62
48,	52,	53,	64,	63
49,	53,	54,	65,	64
50,	54,	55,	66,	65
51,	56,	57,	68,	67
52,	57,	58,	69,	68
53,	58,	59,	70,	69
54,	59,	60,	71,	70
55,	60,	61,	72,	71
56,	61,	62,	73,	72

57,	62,	63,	74,	73
58,	63,	64,	75,	74
59,	64,	65,	76,	75
60,	65,	66,	77,	76
61,	67,	68,	79,	78
62,	68,	69,	80,	79
63,	69,	70,	81,	80
64,	70,	71,	82,	81
65,	71,	72,	83,	82
66,	72,	73,	84,	83
67,	73,	74,	85,	84
68,	74,	75,	86,	85
69,	75,	76,	87,	86
70,	76,	77,	88,	87
71,	78,	79,	90,	89
72,	79,	80,	91,	90
73,	80,	81,	92,	91
74,	81,	82,	93,	92
75,	82,	83,	94,	93
76,	83,	84,	95,	94
77,	84,	85,	96,	95
78,	85,	86,	97,	96
79,	86,	87,	98,	97
80,	87,	88,	99,	98
81,	89,	90,	101,	100
82,	90,	91,	102,	101
83,	91,	92,	103,	102
84,	92,	93,	104,	103
85,	93,	94,	105,	104
86,	94,	95,	106,	105
87,	95,	96,	107,	106
88,	96,	97,	108,	107
89,	97,	98,	109,	108
90,	98,	99,	110,	109
91,	100,	101,	112,	111
92,	101,	102,	113,	112
93,	102,	103,	114,	113
94,	103,	104,	115,	114
95,	104,	105,	116,	115
96,	105,	106,	117,	116
97,	106,	107,	118,	117
98,	107,	108,	119,	118
99,	108,	109,	120,	119
100,	109,	110,	121,	120

PRIM

0,0,0

0,0,0
VIRG
1
1,2
NONI
60,1,3,.01
HEAD
NON-LINEAR RUN step number 1
MATP
4
SOFT
1,0.00,10.00,.350,0,0,0,0,0
2,0,0.001,5,0,0,1
HARD
2,0.000,1000,.2,0,0,0,0,0
0,0,0,0,0,0,2
TOP BEAM
3,0.00,50.00,.35,0,0,0,0,0
0,0,0,0,0,0,3
MINED OUT (FOR AIR ELEMENTS)
4,0.000,1,.2,0,0,0,0,0
4,0,0,0,0,0,4
MATE
12
1,5,1
6,10,2
11,15,1
16,20,2
21,25,1
26,30,2
31,35,1
36,40,2
41,45,1
46,50,2
51,90,1
91,100,3
ZBC
BOXBC
3
-.1,-.1,-.1,10.1,3
9.9,10.1,-.1,10.1,3
-.1,10.1,-.1,.1,2
BC
2
111,4,0,0
121,3,0,-5

TEST BLANK LINES HERE

BLANK LINE1

BLANK LINE2

PERI

2

1,5

Test perimeter NUMBER 1

6,8,19,17,6

2,5

Test perimeter NUMBER 2

17,19,30,28,17

EX

1

2,0,0,0,0

NLIN

OUT1

OUT4

OUT7

RUN

OUT5

OUT6

MENU

STOP

C-2 RESULTS

=====

QUAD -- 2 D FINITE ELEMENT PACKAGE -- Ver 4.00 -- GEMCOM (PTY) LTD.

Module .00

User description : NON-LINEAR RUN step number 1

Page 1

8/24/89 9: 4:34

=====

Number of nodes	121
Number of elements	100
Number of different material types	4
Number of boundary condition nodes	36
Number of perimeters/contours (defined by nodes)	2
PLAIN STRESS(1) PLAIN STRAIN (2) AXI-SYMMETRIC (3)	2
Current mining step number	1

SIGMA-XX = .0000 + .0000 * Y
SIGMA-YY = .0000 + .0000 * Y
SIGMA-XY = .0000 + .0000 * Y

A non-linear run has been requested

Number of Non-linear iterations	60
Acceleration factor for Non-linear iterations	1.300
Convergence limit for non-linear iterations (Units of stress)	.010

User description : NON-LINEAR RUN step number 1

Material properties for various subregions:

Format uses two lines per subregion as follows :

Description, Youngs Modulus, Poissons ratio, Density, Pen, Material type, Aniso/Isotropic

Non-linear properties for this material

Non-linear material codes available are

- 0 Linear material
- 1 No Tension material
- 2 Mohr Coulomb (associated flow rule)
- 3 Mohr Coulomb (non-associated flow rule)
- 4 Special air elements for multi step analysis
- 5 Air elements with Total closure restriction
- 6 Extension failure criterion (not ready yet)
- 7 Non-linear backfill (Quadratic)
- 8 Non-linear backfill (Cubic)
- 10 Joint material (one set) (Also 20,30,40,50)
- 12 Joint material (two sets) (Also 13,23,24,etc)

1	SOFT			10.000	.350	.000	1	2
		Mohr Coulomb material	Tens,Coh,Phi=	.000	.001	5.000		
2	HARD			1000.000	.200	.000	2	0
3	TOP BEAM			50.000	.350	.000	3	0
4	MINED OUT (FOR AIR ELEMENTS)			1.000	.200	.000	4	4
		Special air elements						

QUAD -- 2 D FINITE ELEMENT PACKAGE -- Ver 4.00 -- GEMCOM (PTY) LTD.

Module .00

User description : NON-LINEAR RUN step number 1

Page 3
8/24/89 9: 4:36

Details for 2 perimeters follow:

Perimeter number 1 contains 5 nodes
Description : Test perimeter NUMBER 1

6 8 19 17 6

Perimeter number 2 contains 5 nodes
Description : Test perimeter NUMBER 2

17 19 30 28 17

Start checking nodes

Number of dead nodes

C

Calculate profile of equations

MAX BAND WIDTH =	23 AT	13	25	207
------------------	-------	----	----	-----

Number of equations to be solved

208

Assemble equations

Solve equations

208

Average bandwidth

21.577

Maximum bandwidth

24

Start with iterations for non-linear solution

Cycle	ELTS OUT	Worst	AT	STR ENERGY	Ratio	Sums
1	48	90	1.2943	4.485052	129.4	.000
2	45	80	.5714	1.614001	57.1	.000
3	44	80	.4057	.775284	40.6	.000
4	41	80	.3199	.525486	32.0	.000
5	40	80	.2610	.381384	26.1	.000
6	41	80	.2177	.285388	21.8	.000
7	39	57	.1893	.217535	18.9	.000
8	42	57	.1672	.167750	16.7	.000
9	40	57	.1480	.130444	14.8	.000
10	42	57	.1312	.101973	13.1	.000
11	41	57	.1166	.080099	11.7	.000
12	41	56	.1041	.063089	10.4	.000
13	42	56	.0930	.049847	9.3	.000
14	39	56	.0831	.039488	8.3	.000
15	39	56	.0744	.031286	7.4	.000
16	38	56	.0664	.024867	6.6	.000
17	38	56	.0594	.019776	5.9	.000
18	38	56	.0532	.015759	5.3	.000
19	37	56	.0475	.012574	4.8	.000
20	37	56	.0426	.010028	4.3	.000
21	36	56	.0381	.008012	3.8	.000
22	35	56	.0341	.006392	3.4	.000
23	32	56	.0306	.005104	3.1	.000
24	29	56	.0275	.004046	2.7	.000
25	25	56	.0244	.003206	2.4	.000
26	22	56	.0219	.002520	2.2	.000
27	18	56	.0194	.001991	1.9	.000
28	16	56	.0169	.001555	1.7	.000
29	10	56	.0152	.001236	1.5	.000
30	8	56	.0133	.000926	1.3	.000
31	6	56	.0117	.000726	1.2	.000
32	5	56	.0104	.000573	1.0	.000
33	0	58	.0098	.000467	1.0	.000

Convergence after 33 iterations Maximum stress imbalance = .009826

User description : NON-LINEAR RUN step number 1

ELT	Coordinates		Displacements		Strains			Stresses			Principal Stresses				NO
	X	Y	U	V	E-X	E-Y	E-XY	SIG-X	SIG-Y	SIG-XY	SIG-1	SIG-2	TH-1	TH-2	
1	.50	.50	.0090	-.0189	.018050	-.037896	.002136	-.2359	-.2859	.0015	-.2359	-.2859	2	92	2
2	1.50	.50	.0226	-.0148	.009073	-.029599	.004631	-.2397	-.2880	.0049	-.2392	-.2885	6	96	2
3	2.50	.50	.0259	-.0096	-.002521	-.019255	.003782	-.2495	-.2951	.0072	-.2484	-.2962	9	99	2
5	4.50	.50	.0073	-.0028	-.015138	-.005636	.004167	-.2795	-.2361	.0093	-.2342	-.2814	78	168	2
6	5.50	.50	-.0002	-.0006	.000025	-.001128	-.000005	-.29	-1.25	.00	-.29	-1.25	0	90	
7	6.50	.50	-.0002	-.0005	.000007	-.000989	-.000040	-.27	-1.10	-.02	-.27	-1.10	-1	89	
8	7.50	.50	-.0002	-.0005	.000031	-.000925	-.000061	-.22	-1.02	-.03	-.22	-1.02	-2	88	
9	8.50	.50	-.0001	-.0005	.000074	-.000913	-.000054	-.17	-.99	-.02	-.17	-.99	-2	88	
10	9.50	.50	-.0001	-.0005	.000106	-.000918	-.000022	-.14	-.99	-.01	-.14	-.99	-1	89	
11	.50	1.50	.0083	-.0565	.016643	-.037215	.006614	-.2441	-.2945	.0050	-.2436	-.2949	6	95	2
12	1.50	1.50	.0210	-.0445	.008769	-.029884	.014319	-.2503	-.2936	.0135	-.2465	-.2974	16	106	2
13	2.50	1.50	.0246	-.0293	-.001723	-.020117	.012329	-.2577	-.2919	.0184	-.2497	-.2999	24	114	2
14	3.50	1.50	.0191	-.0187	-.009222	-.012780	.006305	-.2652	-.2796	.0171	-.2539	-.2910	34	124	2
15	4.50	1.50	.0070	-.0085	-.014901	-.005683	.012969	-.2719	-.2426	.0185	-.2336	-.2808	64	154	2
16	5.50	1.50	-.0004	-.0017	.000027	-.001095	-.000012	-.27	-1.21	-.01	-.27	-1.21	0	90	
17	6.50	1.50	-.0004	-.0015	.000021	-.000968	-.000135	-.25	-1.07	-.06	-.24	-1.07	-4	86	
18	7.50	1.50	-.0004	-.0014	.000067	-.000928	-.000207	-.18	-1.01	-.09	-.17	-1.02	-6	84	
19	8.50	1.50	-.0002	-.0014	.000135	-.000945	-.000184	-.11	-1.01	-.08	-.11	-1.02	-5	85	
20	9.50	1.50	-.0001	-.0014	.000182	-.000970	-.000072	-.07	-1.03	-.03	-.07	-1.03	-2	88	
21	.50	2.50	.0075	-.0935	.015016	-.036764	.011390	-.2580	-.3087	.0088	-.2565	-.3102	10	100	2
22	1.50	2.50	.0191	-.0745	.008093	-.029973	.024080	-.2648	-.3013	.0196	-.2563	-.3098	24	114	2
23	2.50	2.50	.0226	-.0499	-.001062	-.021047	.020966	-.2695	-.2920	.0233	-.2549	-.3066	32	122	2
24	3.50	2.50	.0180	-.0319	-.008102	-.013646	.011390	-.2683	-.2735	.0238	-.2470	-.2948	42	132	2
25	4.50	2.50	.0066	-.0143	-.014753	-.005875	.022036	-.2729	-.2480	.0205	-.2365	-.2844	61	151	2
26	5.50	2.50	-.0008	-.0027	.000023	-.001029	-.000045	-.26	-1.14	-.02	-.26	-1.14	-1	89	
27	6.50	2.50	-.0008	-.0024	.000040	-.000913	-.000290	-.21	-1.00	-.12	-.19	-1.02	-8	82	
28	7.50	2.50	-.0007	-.0023	.000147	-.000934	-.000439	-.10	-1.00	-.18	-.06	-1.03	-11	79	
29	8.50	2.50	-.0005	-.0024	.000267	-.001021	-.000370	.01	-1.06	-.15	.04	-1.08	-8	82	
30	9.50	2.50	-.0002	-.0024	.000341	-.001085	-.000142	.08	-1.11	-.06	.08	-1.11	-3	87	
31	.50	3.50	.0067	-.1301	.013387	-.036422	.016342	-.2738	-.3252	.0122	-.2711	-.3279	13	103	2
32	1.50	3.50	.0164	-.1039	.006115	-.028805	.031835	-.2796	-.3106	.0235	-.2669	-.3233	28	118	2
33	2.50	3.50	.0185	-.0707	-.001907	-.020591	.025290	-.2822	-.2955	.0261	-.2619	-.3158	38	128	2
34	3.50	3.50	.0141	-.0462	-.006990	-.014903	.011517	-.2821	-.2688	.0244	-.2502	-.3007	53	143	2
35	4.50	3.50	.0046	-.0206	-.012066	-.006911	.029753	-.2568	-.2308	.0185	-.2211	-.2664	63	153	2
36	5.50	3.50	-.0015	-.0037	-.000011	-.000917	-.000118	-.27	-1.02	-.05	-.26	-1.03	-4	86	
37	6.50	3.50	-.0014	-.0033	.000106	-.000811	-.000631	-.1080	-.8721	-.2627	-.0264	-.9537	-17	73	
38	7.50	3.50	-.0012	-.0033	.000305	-.000968	-.000795	.07	-.99	-.33	.16	-1.09	-16	74	
39	8.50	3.50	-.0008	-.0035	.000478	-.001158	-.000624	.21	-1.15	-.26	.26	-1.20	-10	80	
40	9.50	3.50	-.0003	-.0036	.000583	-.001281	-.000238	.29	-1.26	-.10	.30	-1.27	-4	86	
41	.50	4.50	.0046	-.1648	.009287	-.033085	.021415	-.2888	-.3426	.0148	-.2850	-.3464	14	104	2
42	1.50	4.50	.0095	-.1299	.000452	-.023285	.034770	-.2914	-.3208	.0264	-.2758	-.3364	30	120	2
43	2.50	4.50	.0064	-.0888	-.006745	-.015639	.018310	-.2959	-.3037	.0288	-.2707	-.3289	41	131	2
44	3.50	4.50	-.0004	-.0603	-.006831	-.013358	-.002498	-.2820	-.2584	.0230	-.2443	-.2961	59	149	2
45	4.50	4.50	-.0033	-.0276	.001064	-.007087	.032890	-.2435	-.2076	.0117	-.2041	-.2470	74	164	2
46	5.50	4.50	-.0027	-.0045	.000243	-.000739	-.000556	.0651	-.7532	-.2316	.1261	-.8142	-15	75	
47	6.50	4.50	-.0024	-.0041	.000358	-.000748	-.001091	.19	-.73	-.45	.38	-.92	-22	68	
48	7.50	4.50	-.0019	-.0043	.000532	-.001048	-.001172	.30	-1.02	-.49	.46	-1.18	-18	72	
49	8.50	4.50	-.0013	-.0047	.000736	-.001352	-.000935	.44	-1.30	-.39	.53	-1.38	-12	78	
50	9.50	4.50	-.0005	-.0050	.000904	-.001576	-.000394	.57	-1.50	-.18	.58	-1.51	-5	85	

User description : NON-LINEAR RUN step number 1

8/24/89 9:12:37

ELT	Coordinates		Displacements		Strains			Stresses			Principal Stresses			
	X	Y	U	V	E-X	E-Y	E-XY	SIG-X	SIG-Y	SIG-XY	SIG-1	SIG-2	TH-1	TH-2
51	.50	5.50	-.0322	-.1615	-.064449	.039825	-.032464	-.3637	-.3104	-.0158	-.3061	-.3680	-75	15
52	1.50	5.50	-.1073	-.1092	-.085791	.064727	-.158727	-.3445	-.3147	-.0288	-.2972	-.3620	-59	31
53	2.50	5.50	-.2046	-.0500	-.108703	.093334	-.351433	-.3311	-.3072	-.0322	-.2848	-.3534	-55	35
54	3.50	5.50	-.3175	-.0132	-.117069	.107536	-.589923	-.3294	-.3079	-.0344	-.2826	-.3547	-54	36
55	4.50	5.50	-.4242	.0150	-.096466	.092371	-.794630	-.3203	-.3037	-.0358	-.2753	-.3488	-52	38
56	5.50	5.50	-.5025	.0176	-.060129	.044922	-1.028030	-.52	-.51	-.05	-.46	-.57	-47	43
57	6.50	5.50	-.5292	-.0229	.006822	-.036878	-1.103670	-.72	-.73	-.07	-.65	-.80	-43	47
58	7.50	5.50	-.4781	-.0799	.095469	-.150105	-1.014472	-.99	-1.03	-.09	-.91	-1.10	-39	51
59	8.50	5.50	-.3378	-.1386	.184998	-.266508	-.727247	-1.22	-1.33	-.11	-1.16	-1.40	-31	59
60	9.50	5.50	-.1227	-.1800	.245319	-.348385	-.272353	-1.36	-1.59	-.07	-1.34	-1.61	-15	75
61	.50	6.50	-.0770	-.0738	-.153936	.135922	.040307	-.3466	-.2815	.0058	-.2810	-.3472	85	175
62	1.50	6.50	-.2486	.0091	-.189365	.171839	.046815	-.3649	-.2977	.0075	-.2968	-.3657	84	174
63	2.50	6.50	-.4603	.1054	-.233903	.217493	-.021460	-.3808	-.3108	.0025	-.3107	-.3809	88	178
64	3.50	6.50	-.7070	.1623	-.259692	.243548	-.140429	-.4003	-.3301	-.0087	-.3290	-.4014	-83	7
65	4.50	6.50	-.9549	.1688	-.236027	.215279	-.245989	-.4510	-.3880	-.0260	-.3787	-.4604	-70	20
66	5.50	6.50	-1.1466	.0986	-.147292	.117267	-.615958	-.55	-.51	-.05	-.48	-.58	-55	35
67	6.50	6.50	-1.2205	-.0647	-.000546	-.046695	-.530420	-.72	-.78	-.06	-.68	-.82	-32	58
68	7.50	6.50	-1.1169	-.2884	.207806	-.266927	-.573039	-.89	-1.04	-.05	-.88	-1.08	-16	74
69	8.50	6.50	-.7987	-.5211	.428469	-.498439	-.467720	-1.08	-1.30	-.03	-1.08	-1.30	-8	82
70	9.50	6.50	-.2922	-.6856	.584486	-.662844	-.205459	-1.24	-1.49	-.01	-1.24	-1.49	-3	87
71	.50	7.50	-.0695	.0551	-.138978	.121485	.120398	-.3382	-.2758	.0101	-.2742	-.3398	81	171
72	1.50	7.50	-.2300	.1785	-.181945	.166988	.256982	-.3511	-.2936	.0187	-.2881	-.3587	74	164
73	2.50	7.50	-.4403	.3266	-.238723	.224922	.283847	-.3719	-.3148	.0214	-.3077	-.3790	72	162
74	3.50	7.50	-.6968	.4141	-.274397	.260075	.227074	-.3925	-.3317	.0196	-.3259	-.3983	74	164
75	4.50	7.50	-.9620	.3939	-.255937	.234864	.138138	-.4601	-.3863	.0157	-.3831	-.4633	78	168
76	5.50	7.50	-1.1762	.2265	-.172463	.138463	-.024785	-.57	-.47	.01	-.47	-.57	83	173
77	6.50	7.50	-1.2764	-.1012	-.027840	-.026483	-.181988	-.67	-.80	-.02	-.67	-.81	-9	81
78	7.50	7.50	-1.1936	-.5517	.193424	-.259780	-.328126	-.92	-1.10	-.01	-.91	-1.10	-2	88
79	8.50	7.50	-.8714	-1.0311	.450993	-.521587	-.354121	-1.09	-1.32	-.01	-1.09	-1.32	-1	89
80	9.50	7.50	-.3229	-1.3755	.645866	-.716824	-.197096	-1.19	-1.43	.00	-1.19	-1.43	-1	89
81	.50	8.50	-.0046	.1131	-.009137	-.005476	.223201	-.2626	-.2429	.0240	-.2268	-.2787	56	146
82	1.50	8.50	-.0471	.2919	-.075858	.059836	.499472	-.3731	-.3517	.0372	-.3230	-.4011	53	143
83	2.50	8.50	-.1538	.5037	-.137519	.129200	.618325	-.3289	-.3084	.0345	-.2827	-.3548	53	143
84	3.50	8.50	-.3122	.6310	-.179440	.173667	.842553	-.3180	-.2974	.0332	-.2730	-.3425	54	144
85	4.50	8.50	-.4948	.5989	-.185596	.175212	.591422	-.3841	-.3425	.0362	-.3155	-.3910	53	143
86	5.50	8.50	-.6624	.3580	-.149768	.124579	.440753	-.4935	-.4763	.0472	-.4369	-.5329	50	140
87	6.50	8.50	-.7722	-.1057	-.069745	.017636	.219016	-.74	-.76	.07	-.69	-.82	41	131
88	7.50	8.50	-.7723	-.7534	.069472	-.143593	-.054514	-.96	-1.09	.07	-.93	-1.12	22	112
89	8.50	8.50	-.6065	-1.4692	.262100	-.354571	-.281504	-1.26	-1.50	.04	-1.25	-1.50	8	98
90	9.50	8.50	-.2377	-2.0087	.475491	-.549540	-.234837	-1.14	-1.36	.01	-1.14	-1.36	2	92
91	.50	9.50	-.0034	.1047	-.006850	-.011260	.081789	-1.04	-1.20	1.51	.40	-2.63	43	133
92	1.50	9.50	-.0146	.3260	-.015507	.008236	.062817	-.89	-.01	1.16	.79	-1.69	55	145
93	2.50	9.50	-.0293	.5711	-.013948	.005526	.046909	-.88	-.16	.87	.42	-1.48	56	146
94	3.50	9.50	-.0432	.7208	-.013710	.005881	.033170	-.85	-.12	.81	.23	-1.20	60	150
95	4.50	9.50	-.0557	.6887	-.011411	.004344	.020856	-.7280	-.1445	.3862	.0478	-.9202	84	154
96	5.50	9.50	-.0648	.4208	-.006677	.000863	.002677	-.4985	-.2192	.0496	-.2107	-.5071	80	170
97	6.50	9.50	-.0679	-.0991	.000450	-.004410	-.025494	-.1544	-.3344	-.4721	.2362	-.7250	-40	50
98	7.50	9.50	-.0629	-.8313	.009488	-.012208	-.071549	.23	-.57	-1.32	1.22	-1.55	-37	53
99	8.50	9.50	-.0514	-1.6517	.013431	-.010323	-.135588	.63	-.25	-2.51	2.74	-2.36	-40	50
100	9.50	9.50	-.0224	-2.3167	.044733	-.070538	-.219996	.54	-3.73	-4.07	3.01	-6.19	-31	59

MODAL SOLUTIONS

NODE	Coordinates		BC	<- Nodal forces ->		<- Displacements ->		<-- Exponent format -->	
	X	Y		FX	FY	U	V	U	V
1	.000	.000	4	.11562	.15080	.00000	.00000	.000000E+00	.000000E+00
2	1.000	.000	2	.00000	.29535	.01853	.00000	.185301E-01	.000000E+00
3	2.000	.000	2	.00000	.28700	.02769	.00000	.276925E-01	.000000E+00
4	3.000	.000	2	.00000	.28019	.02491	.00000	.249131E-01	.000000E+00
5	4.000	.000	2	.00000	.26369	.01510	.00000	.150957E-01	.000000E+00
6	5.000	.000	2	.00000	.75585	-.00019	.00000	-.192660E-03	.000000E+00
7	6.000	.000	2	.00000	1.16794	-.00017	.00000	-.171466E-03	.000000E+00
8	7.000	.000	2	.00000	1.05365	-.00017	.00000	-.168522E-03	.000000E+00
9	8.000	.000	2	.00000	1.00075	-.00015	.00000	-.146067E-03	.000000E+00
10	9.000	.000	2	.00000	.98507	-.00009	.00000	-.868748E-04	.000000E+00
11	10.000	.000	4	-.06909	.48157	.00000	.00000	.000000E+00	.000000E+00
12	.000	1.000	3	.23681	.00000	.00000	-.04051	.000000E+00	-.405118E-01
13	1.000	1.000	0	.00000	.00000	.01757	-.03528	.175693E-01	-.352794E-01
14	2.000	1.000	0	.00000	.00000	.02655	-.02392	.265528E-01	-.239179E-01
15	3.000	1.000	0	.00000	.00000	.02429	-.01459	.242906E-01	-.145922E-01
16	4.000	1.000	0	.00000	.00000	.01470	-.01005	.146960E-01	-.100532E-01
17	5.000	1.000	1	.00000	.00000	-.00029	-.00122	-.292694E-03	-.121965E-02
18	6.000	1.000	0	.00000	.00000	-.00026	-.00104	-.264279E-03	-.103685E-02
19	7.000	1.000	1	.00000	.00000	-.00025	-.00094	-.252912E-03	-.940266E-03
20	8.000	1.000	0	.00000	.00000	-.00021	-.00091	-.212771E-03	-.910338E-03
21	9.000	1.000	0	.00000	.00000	-.00012	-.00091	-.124192E-03	-.914894E-03
22	10.000	1.000	3	-.10181	.00000	.00000	-.00092	.000000E+00	-.920994E-03
23	.000	2.000	3	.24990	.00000	.00000	-.08003	.000000E+00	-.800349E-01
24	1.000	2.000	0	.00000	.00000	.01572	-.07019	.157175E-01	-.701870E-01
25	2.000	2.000	0	.00000	.00000	.02427	-.04878	.242727E-01	-.487791E-01
26	3.000	2.000	0	.00000	.00000	.02309	-.02997	.230898E-01	-.299660E-01
27	4.000	2.000	0	.00000	.00000	.01424	-.02024	.142411E-01	-.202388E-01
28	5.000	2.000	1	.00000	.00000	-.00057	-.00240	-.572334E-03	-.240017E-02
29	6.000	2.000	0	.00000	.00000	-.00055	-.00205	-.546068E-03	-.204570E-02
30	7.000	2.000	1	.00000	.00000	-.00052	-.00187	-.515476E-03	-.186710E-02
31	8.000	2.000	0	.00000	.00000	-.00042	-.00184	-.422054E-03	-.183860E-02
32	9.000	2.000	0	.00000	.00000	-.00024	-.00188	-.240147E-03	-.187648E-02
33	10.000	2.000	3	.00872	.00000	.00000	-.00190	.000000E+00	-.189936E-02
34	.000	3.000	3	.26348	.00000	.00000	-.11904	.000000E+00	-.119042E+00
35	1.000	3.000	0	.00000	.00000	.01431	-.10471	.143144E-01	-.104707E+00
36	2.000	3.000	0	.00000	.00000	.02193	-.07420	.219254E-01	-.742050E-01
37	3.000	3.000	0	.00000	.00000	.02098	-.04663	.209844E-01	-.466334E-01
38	4.000	3.000	0	.00000	.00000	.01383	-.03086	.136282E-01	-.308630E-01
39	5.000	3.000	0	.00000	.00000	-.00106	-.00353	-.106381E-02	-.352516E-02
40	6.000	3.000	0	.00000	.00000	-.00104	-.00298	-.104447E-02	-.297914E-02
41	7.000	3.000	0	.00000	.00000	-.00100	-.00276	-.995518E-03	-.275931E-02
42	8.000	3.000	0	.00000	.00000	-.00079	-.00281	-.794451E-03	-.281380E-02
43	9.000	3.000	0	.00000	.00000	-.00044	-.00294	-.441393E-03	-.294318E-02
44	10.000	3.000	3	.19425	.00000	.00000	-.00300	.000000E+00	-.300345E-02
45	.000	4.000	3	.27262	.00000	.00000	-.15840	.000000E+00	-.158399E+00
46	1.000	4.000	0	.00000	.00000	.01246	-.13819	.124596E-01	-.138195E+00
47	2.000	4.000	0	.00000	.00000	.01706	-.09833	.170795E-01	-.983265E-01
48	3.000	4.000	0	.00000	.00000	.01421	-.06369	.142070E-01	-.636940E-01
49	4.000	4.000	0	.00000	.00000	.00758	-.04361	.758341E-02	-.436081E-01
50	5.000	4.000	0	.00000	.00000	-.00186	-.00460	-.185655E-02	-.460174E-02

User description : NON-LINEAR RUN step number 1

NODAL SOLUTIONS

NODE	Coordinates		BC	<- Nodal forces ->		<- Displacements ->		<-- Exponent format -->	
	X	Y		FX	FY	U	V	U	V
51	6.000	4.000	0	.00000	.00000	-.00190	-.00374	-.189837E-02	-.373734E-02
52	7.000	4.000	0	.00000	.00000	-.00174	-.00362	-.173610E-02	-.362375E-02
53	8.000	4.000	0	.00000	.00000	-.00133	-.00389	-.132756E-02	-.388564E-02
54	9.000	4.000	0	.00000	.00000	-.00073	-.00419	-.725399E-03	-.418808E-02
55	10.000	4.000	3	.45258	.00000	.00000	-.00432	.000000E+00	-.432017E-02
56	.000	5.000	3	.11972	.00000	.00000	-.19587	.000000E+00	-.195868E+00
57	1.000	5.000	0	.00000	.00000	.00611	-.16690	.611411E-02	-.166896E+00
58	2.000	5.000	0	.00000	.00000	.00240	-.11620	.239796E-02	-.116196E+00
59	3.000	5.000	0	.00000	.00000	-.00822	-.07710	-.821914E-02	-.771013E-01
60	4.000	5.000	0	.00000	.00000	-.01526	-.05692	-.152569E-01	-.569158E-01
61	5.000	5.000	0	.00000	.00000	-.00369	-.00547	-.368961E-02	-.546823E-02
62	6.000	5.000	0	.00000	.00000	-.00316	-.00435	-.316116E-02	-.434833E-02
63	7.000	5.000	0	.00000	.00000	-.00261	-.00451	-.260755E-02	-.450882E-02
64	8.000	5.000	0	.00000	.00000	-.00195	-.00510	-.195173E-02	-.509570E-02
65	9.000	5.000	0	.00000	.00000	-.00108	-.00568	-.108245E-02	-.568135E-02
66	10.000	5.000	3	-1.20314	.00000	.00000	-.00598	.000000E+00	-.597946E-02
67	.000	6.000	3	.51436	.00000	.00000	-.16517	.000000E+00	-.165170E+00
68	1.000	6.000	0	.00000	.00000	-.13501	-.11794	-.135013E+00	-.117943E+00
69	2.000	6.000	0	.00000	.00000	-.30288	-.03569	-.302878E+00	-.356947E-01
70	3.000	6.000	0	.00000	.00000	-.50967	.02907	-.509666E+00	.290655E-01
71	4.000	6.000	0	.00000	.00000	-.73677	.05199	-.736767E+00	.519897E-01
72	5.000	6.000	0	.00000	.00000	-.94127	.07037	-.941267E+00	.703685E-01
73	6.000	6.000	0	.00000	.00000	-1.06205	.00966	-.106205E+01	.965846E-02
74	7.000	6.000	0	.00000	.00000	-1.04896	-.09227	-.104896E+01	-.922719E-01
75	8.000	6.000	0	.00000	.00000	-.85868	-.21754	-.858683E+00	-.217542E+00
76	9.000	6.000	0	.00000	.00000	-.48956	-.32625	-.489555E+00	-.326247E+00
77	10.000	6.000	3	-.83295	.00000	.00000	-.38218	.000000E+00	-.382182E+00
78	.000	7.000	3	.51417	.00000	.00000	-.04125	.000000E+00	-.412518E-01
79	1.000	7.000	0	.00000	.00000	-.17286	.02998	-.172860E+00	.299828E-01
80	2.000	7.000	0	.00000	.00000	-.38372	.16006	-.383724E+00	.160057E+00
81	3.000	7.000	0	.00000	.00000	-.64474	.26830	-.644742E+00	.268299E+00
82	4.000	7.000	0	.00000	.00000	-.93703	.29985	-.937025E+00	.299852E+00
83	5.000	7.000	0	.00000	.00000	-1.20458	.25307	-.120458E+01	.253065E+00
84	6.000	7.000	0	.00000	.00000	-1.37838	.06149	-.137838E+01	.614948E-01
85	7.000	7.000	0	.00000	.00000	-1.39256	-.23750	-.139256E+01	-.237499E+00
86	8.000	7.000	0	.00000	.00000	-1.16723	-.60617	-.116723E+01	-.606170E+00
87	9.000	7.000	0	.00000	.00000	-.67942	-.93450	-.679417E+00	-.934499E+00
88	10.000	7.000	3	-.79583	.00000	.00000	-1.09962	.000000E+00	-.109962E+01
89	.000	8.000	3	.49778	.00000	.00000	.06495	.000000E+00	.649540E-01
90	1.000	8.000	0	.00000	.00000	-.10510	.16675	-.105096E+00	.166747E+00
91	2.000	8.000	0	.00000	.00000	-.25812	.35727	-.258122E+00	.357270E+00
92	3.000	8.000	0	.00000	.00000	-.47455	.52093	-.474551E+00	.520928E+00
93	4.000	8.000	0	.00000	.00000	-.73106	.56737	-.731062E+00	.567372E+00
94	5.000	8.000	0	.00000	.00000	-.97538	.45527	-.975382E+00	.455274E+00
95	6.000	8.000	0	.00000	.00000	-1.14651	.13621	-.114651E+01	.136213E+00
96	7.000	8.000	0	.00000	.00000	-1.18801	-.36518	-.118801E+01	-.365182E+00
97	8.000	8.000	0	.00000	.00000	-1.02649	-.99805	-.102649E+01	-.998046E+00
98	9.000	8.000	0	.00000	.00000	-.61232	-.15858	-.612316E+00	-.158580E+01
99	10.000	8.000	3	-.82792	.00000	.00000	-1.88197	.000000E+00	-.188197E+01
100	.000	9.000	3	-1.95373	.00000	.00000	.03403	.000000E+00	.340282E-01

NODAL SOLUTIONS

NODE	Coordinates		BC	<- Nodal forces ->		<- Displacements ->		<-- Exponent format -->	
	X	Y		FX	FY	U	V	U	V
101	1.000	9.000	0	.00000	.00000	.08682	.18672	.868211E-01	.186720E+00
102	2.000	9.000	0	.00000	.00000	.08813	.45697	.881320E-01	.456968E+00
103	3.000	9.000	0	.00000	.00000	.02952	.67963	.295229E-01	.679630E+00
104	4.000	9.000	0	.00000	.00000	-.07285	.75600	-.728458E-01	.756004E+00
105	5.000	9.000	0	.00000	.00000	-.19972	.61706	-.199717E+00	.617065E+00
106	6.000	9.000	0	.00000	.00000	-.32812	.22358	-.328124E+00	.223580E+00
107	7.000	9.000	0	.00000	.00000	-.42612	-.41728	-.426116E+00	-.417277E+00
108	8.000	9.000	0	.00000	.00000	-.44869	-1.23314	-.448690E+00	-1.23314E+01
109	9.000	9.000	0	.00000	.00000	-.33867	-2.05985	-.338666E+00	-2.05985E+01
110	10.000	9.000	3	6.13171	.00000	.00000	-2.50700	.000000E+00	-2.50700E+01
111	.000	10.000	4	2.81732	-1.73187	.00000	.00000	.000000E+00	.000000E+00
112	1.000	10.000	0	.00000	.00000	-.10052	.19823	-.100521E+00	.198228E+00
113	2.000	10.000	0	.00000	.00000	-.13284	.46193	-.132845E+00	.461932E+00
114	3.000	10.000	0	.00000	.00000	-.10213	.68572	-.102132E+00	.685719E+00
115	4.000	10.000	0	.00000	.00000	-.02718	.76168	-.271828E-01	.761677E+00
116	5.000	10.000	0	.00000	.00000	.07687	.62008	.768673E-01	.620080E+00
117	6.000	10.000	0	.00000	.00000	.19192	.22229	.191919E+00	.222292E+00
118	7.000	10.000	0	.00000	.00000	.29081	-.42481	.290812E+00	-.424808E+00
119	8.000	10.000	0	.00000	.00000	.33236	-1.25002	.332362E+00	-1.25002E+01
120	9.000	10.000	0	.00000	.00000	.24920	-2.06361	.249200E+00	-2.06361E+01
121	10.000	10.000	3	-6.60452	-5.00000	.00000	-2.64431	.000000E+00	-2.64431E+01

Number of nodes	121
Number of elements	100
Number of different material types	4
Number of boundary condition nodes	36
Number of perimeters/contours (defined by nodes)	2
PLAIN STRESS(1) PLAIN STRAIN (2) AXI-SYMMETRIC (3)	2

Current mining step number	1
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SIGMA-XX = .0000 + .0000 * Y
 SIGMA-YY = .0000 + .0000 * Y
 SIGMA-XY = .0000 + .0000 * Y

A non-linear run has been requested

Number of Non-linear iterations	60
Acceleration factor for Non-linear iterations	1.300
Convergence limit for non-linear iterations (Units of stress)	.010

User description : NON-LINEAR RUN step number 1

Elt	<----- Nodes ----->					Coordinates		Area	<-- Primitive stresses --->		
						X	Y		P-XX	P-YY	P-XY
1	1	2	13	12		.500	.500	1.00	.000	.000	.000
2	2	3	14	13		1.500	.500	1.00	.000	.000	.000
3	3	4	15	14		2.500	.500	1.00	.000	.000	.000
4	4	5	16	15		3.500	.500	1.00	.000	.000	.000
5	5	6	17	16		4.500	.500	1.00	.000	.000	.000
6	6	7	18	17		5.500	.500	1.00	.000	.000	.000
7	7	8	19	18		6.500	.500	1.00	.000	.000	.000
8	8	9	20	19		7.500	.500	1.00	.000	.000	.000
9	9	10	21	20		8.500	.500	1.00	.000	.000	.000
10	10	11	22	21		9.500	.500	1.00	.000	.000	.000
11	12	13	24	23		.500	1.500	1.00	.000	.000	.000
12	13	14	25	24		1.500	1.500	1.00	.000	.000	.000
13	14	15	26	25		2.500	1.500	1.00	.000	.000	.000
14	15	16	27	26		3.500	1.500	1.00	.000	.000	.000
15	16	17	28	27		4.500	1.500	1.00	.000	.000	.000
16	17	18	29	28		5.500	1.500	1.00	.000	.000	.000
17	18	19	30	29		6.500	1.500	1.00	.000	.000	.000
18	19	20	31	30		7.500	1.500	1.00	.000	.000	.000
19	20	21	32	31		8.500	1.500	1.00	.000	.000	.000
20	21	22	33	32		9.500	1.500	1.00	.000	.000	.000
21	23	24	35	34		.500	2.500	1.00	.000	.000	.000
22	24	25	36	35		1.500	2.500	1.00	.000	.000	.000
23	25	26	37	36		2.500	2.500	1.00	.000	.000	.000
24	26	27	38	37		3.500	2.500	1.00	.000	.000	.000
25	27	28	39	38		4.500	2.500	1.00	.000	.000	.000
26	28	29	40	39		5.500	2.500	1.00	.000	.000	.000
27	29	30	41	40		6.500	2.500	1.00	.000	.000	.000
28	30	31	42	41		7.500	2.500	1.00	.000	.000	.000
29	31	32	43	42		8.500	2.500	1.00	.000	.000	.000
30	32	33	44	43		9.500	2.500	1.00	.000	.000	.000
31	34	35	46	45		.500	3.500	1.00	.000	.000	.000
32	35	36	47	46		1.500	3.500	1.00	.000	.000	.000
33	36	37	48	47		2.500	3.500	1.00	.000	.000	.000
34	37	38	49	48		3.500	3.500	1.00	.000	.000	.000
35	38	39	50	49		4.500	3.500	1.00	.000	.000	.000
36	39	40	51	50		5.500	3.500	1.00	.000	.000	.000
37	40	41	52	51		6.500	3.500	1.00	.000	.000	.000
38	41	42	53	52		7.500	3.500	1.00	.000	.000	.000
39	42	43	54	53		8.500	3.500	1.00	.000	.000	.000
40	43	44	55	54		9.500	3.500	1.00	.000	.000	.000
41	45	46	57	56		.500	4.500	1.00	.000	.000	.000
42	46	47	58	57		1.500	4.500	1.00	.000	.000	.000
43	47	48	59	58		2.500	4.500	1.00	.000	.000	.000
44	48	49	60	59		3.500	4.500	1.00	.000	.000	.000
45	49	50	61	60		4.500	4.500	1.00	.000	.000	.000
46	50	51	62	61		5.500	4.500	1.00	.000	.000	.000
47	51	52	63	62		6.500	4.500	1.00	.000	.000	.000
48	52	53	64	63		7.500	4.500	1.00	.000	.000	.000
49	53	54	65	64		8.500	4.500	1.00	.000	.000	.000
50	54	55	66	65		9.500	4.500	1.00	.000	.000	.000

User description : NON-LINEAR RUN step number 1

Elt	<----- Nodes ----->					Coordinates	Area	<-- Primitive stresses --->		
								P-XX	P-YY	P-XY
51	56	57	68	67		.500 5.500	1.00	.000	.000	.000
52	57	58	68	68		1.500 5.500	1.00	.000	.000	.000
53	58	59	70	69		2.500 5.500	1.00	.000	.000	.000
54	59	60	71	70		3.500 5.500	1.00	.000	.000	.000
55	60	61	72	71		4.500 5.500	1.00	.000	.000	.000
56	61	62	73	72		5.500 5.500	1.00	.000	.000	.000
57	62	63	74	73		6.500 5.500	1.00	.000	.000	.000
58	63	64	75	74		7.500 5.500	1.00	.000	.000	.000
59	64	65	76	75		8.500 5.500	1.00	.000	.000	.000
60	65	66	77	76		9.500 5.500	1.00	.000	.000	.000
61	67	68	79	78		.500 6.500	1.00	.000	.000	.000
62	68	69	80	79		1.500 6.500	1.00	.000	.000	.000
63	69	70	81	80		2.500 6.500	1.00	.000	.000	.000
64	70	71	82	81		3.500 6.500	1.00	.000	.000	.000
65	71	72	83	82		4.500 6.500	1.00	.000	.000	.000
66	72	73	84	83		5.500 6.500	1.00	.000	.000	.000
67	73	74	85	84		6.500 6.500	1.00	.000	.000	.000
68	74	75	86	85		7.500 6.500	1.00	.000	.000	.000
69	75	76	87	86		8.500 6.500	1.00	.000	.000	.000
70	76	77	88	87		9.500 6.500	1.00	.000	.000	.000
71	78	79	90	89		.500 7.500	1.00	.000	.000	.000
72	79	80	91	90		1.500 7.500	1.00	.000	.000	.000
73	80	81	92	91		2.500 7.500	1.00	.000	.000	.000
74	81	82	93	92		3.500 7.500	1.00	.000	.000	.000
75	82	83	94	93		4.500 7.500	1.00	.000	.000	.000
76	83	84	95	94		5.500 7.500	1.00	.000	.000	.000
77	84	85	96	95		6.500 7.500	1.00	.000	.000	.000
78	85	86	97	96		7.500 7.500	1.00	.000	.000	.000
79	86	87	98	97		8.500 7.500	1.00	.000	.000	.000
80	87	88	99	98		9.500 7.500	1.00	.000	.000	.000
81	89	90	101	100		.500 8.500	1.00	.000	.000	.000
82	90	91	102	101		1.500 8.500	1.00	.000	.000	.000
83	91	92	103	102		2.500 8.500	1.00	.000	.000	.000
84	92	93	104	103		3.500 8.500	1.00	.000	.000	.000
85	93	94	105	104		4.500 8.500	1.00	.000	.000	.000
86	94	95	106	105		5.500 8.500	1.00	.000	.000	.000
87	95	96	107	106		6.500 8.500	1.00	.000	.000	.000
88	96	97	108	107		7.500 8.500	1.00	.000	.000	.000
89	97	98	109	108		8.500 8.500	1.00	.000	.000	.000
90	98	99	110	109		9.500 8.500	1.00	.000	.000	.000
91	100	101	112	111		.500 9.500	1.00	.000	.000	.000
92	101	102	113	112		1.500 9.500	1.00	.000	.000	.000
93	102	103	114	113		2.500 9.500	1.00	.000	.000	.000
94	103	104	115	114		3.500 9.500	1.00	.000	.000	.000
95	104	105	116	115		4.500 9.500	1.00	.000	.000	.000
96	105	106	117	116		5.500 9.500	1.00	.000	.000	.000
97	106	107	118	117		6.500 9.500	1.00	.000	.000	.000
98	107	108	119	118		7.500 9.500	1.00	.000	.000	.000
99	108	109	120	119		8.500 9.500	1.00	.000	.000	.000
100	109	110	121	120		9.500 9.500	1.00	.000	.000	.000

Material properties for various subregions:

Format uses two lines per subregion as follows :

Description, Youngs Modulus, Poissons ratio, Density, Pen, Material type, Aniso/Isotropic

Non-linear properties for this material

Non-linear material codes available are

- 0 Linear material
- 1 No Tension material
- 2 Mohr Coulomb (associated flow rule)
- 3 Mohr Coulomb (non-associated flow rule)
- 4 Special air elements for multi step analysis
- 5 Air elements with Total closure restriction
- 6 Extension failure criterion (not ready yet)
- 7 Non-linear backfill (Quadratic)
- 8 Non-linear backfill (Cubic)
- 10 Joint material (one set) (Also 20,30,40,50)
- 12 Joint material (two sets) (Also 13,23,24,etc)

1	SOFT	Mohr Coulomb material	Tens, Coh, Phi=	10.000 .000	.350 .001	.000 5.000	1	2
2	HARD			1000.000	.200	.000	2	0
3	TOP BEAM			50.000	.350	.000	3	0
4	MINED OUT (FOR AIR ELEMENTS)	Special air elements		1.000	.200	.000	4	4

User description : NON-LINEAR RUN step number 1

NODAL SOLUTIONS

NODE	Coordinates		BC	<- Nodal forces ->		<- Displacements ->		<-- Exponent format -->	
	X	Y		FX	FY	U	V	U	V
1	.000	.000	4	.11562	.15080	.00000	.00000	.000000E+00	.000000E+00
2	1.000	.000	2	.00000	.29535	.01853	.00000	.185301E-01	.000000E+00
3	2.000	.000	2	.00000	.28700	.02769	.00000	.276925E-01	.000000E+00
4	3.000	.000	2	.00000	.28019	.02491	.00000	.249131E-01	.000000E+00
5	4.000	.000	2	.00000	.26369	.01510	.00000	.150957E-01	.000000E+00
6	5.000	.000	2	.00000	.75585	-.00019	.00000	-.192660E-03	.000000E+00
7	6.000	.000	2	.00000	1.16794	-.00017	.00000	-.171466E-03	.000000E+00
8	7.000	.000	2	.00000	1.05365	-.00017	.00000	-.168522E-03	.000000E+00
9	8.000	.000	2	.00000	1.00075	-.00015	.00000	-.146067E-03	.000000E+00
10	9.000	.000	2	.00000	.98507	-.00009	.00000	-.868748E-04	.000000E+00
11	10.000	.000	4	-.06909	.49157	.00000	.00000	.000000E+00	.000000E+00
12	.000	1.000	3	.23681	.00000	.00000	-.04051	.000000E+00	-.405118E-01
13	1.000	1.000	0	.00000	.00000	.01757	-.03528	.175693E-01	-.352794E-01
14	2.000	1.000	0	.00000	.00000	.02392	-.02392	.265528E-01	-.239179E-01
15	3.000	1.000	0	.00000	.00000	.02429	-.01459	.242906E-01	-.145922E-01
16	4.000	1.000	0	.00000	.00000	.01470	-.01005	.146960E-01	-.100532E-01
17	5.000	1.000	1	.00000	.00000	-.00029	-.00122	-.292694E-03	-.121965E-02
18	6.000	1.000	0	.00000	.00000	-.00026	-.00104	-.264279E-03	-.103685E-02
19	7.000	1.000	1	.00000	.00000	-.00025	-.00094	-.252912E-03	-.940266E-03
20	8.000	1.000	0	.00000	.00000	-.00021	-.00091	-.212771E-03	-.910338E-03
21	9.000	1.000	0	.00000	.00000	-.00012	-.00091	-.124192E-03	-.914894E-03
22	10.000	1.000	3	-.10181	.00000	.00000	-.00092	.000000E+00	-.920994E-03
23	.000	2.000	3	.24990	.00000	.00000	-.08003	.000000E+00	-.800349E-01
24	1.000	2.000	0	.00000	.00000	.01572	-.07019	.157175E-01	-.701870E-01
25	2.000	2.000	0	.00000	.00000	.02427	-.04878	.242727E-01	-.487791E-01
26	3.000	2.000	0	.00000	.00000	.02309	-.02997	.230898E-01	-.299660E-01
27	4.000	2.000	0	.00000	.00000	.01424	-.02024	.142411E-01	-.202388E-01
28	5.000	2.000	1	.00000	.00000	-.00057	-.00240	-.572334E-03	-.240017E-02
29	6.000	2.000	0	.00000	.00000	-.00055	-.00205	-.546068E-03	-.204570E-02
30	7.000	2.000	1	.00000	.00000	-.00052	-.00187	-.515476E-03	-.186710E-02
31	8.000	2.000	0	.00000	.00000	-.00042	-.00184	-.422054E-03	-.183860E-02
32	9.000	2.000	0	.00000	.00000	-.00024	-.00188	-.240147E-03	-.187648E-02
33	10.000	2.000	3	.00872	.00000	.00000	-.00190	.000000E+00	-.189936E-02
34	.000	3.000	3	.26348	.00000	.00000	-.11904	.000000E+00	-.119042E+00
35	1.000	3.000	0	.00000	.00000	.01431	-.10471	.143144E-01	-.104707E+00
36	2.000	3.000	0	.00000	.00000	.02193	-.07420	.219254E-01	-.742050E-01
37	3.000	3.000	0	.00000	.00000	.02098	-.04663	.209844E-01	-.466334E-01
38	4.000	3.000	0	.00000	.00000	.01363	-.03086	.136282E-01	-.308630E-01
39	5.000	3.000	0	.00000	.00000	-.00106	-.00353	-.106381E-02	-.352516E-02
40	6.000	3.000	0	.00000	.00000	-.00104	-.00298	-.104447E-02	-.297914E-02
41	7.000	3.000	0	.00000	.00000	-.00100	-.00276	-.995518E-03	-.275931E-02
42	8.000	3.000	0	.00000	.00000	-.00079	-.00281	-.794451E-03	-.281380E-02
43	9.000	3.000	0	.00000	.00000	-.00044	-.00294	-.441393E-03	-.294318E-02
44	10.000	3.000	3	.19425	.00000	.00000	-.00300	.000000E+00	-.300345E-02
45	.000	4.000	3	.27262	.00000	.00000	-.15840	.000000E+00	-.158399E+00
46	1.000	4.000	0	.00000	.00000	.01246	-.13819	.124596E-01	-.138195E+00
47	2.000	4.000	0	.00000	.00000	.01708	-.09833	.170795E-01	-.983265E-01
48	3.000	4.000	0	.00000	.00000	.01421	-.06369	.142070E-01	-.636940E-01
49	4.000	4.000	0	.00000	.00000	.00758	-.04361	.758341E-02	-.436081E-01
50	5.000	4.000	0	.00000	.00000	-.00186	-.00460	-.185655E-02	-.460174E-02

User description : NON-LINEAR RUN step number 1

NODAL SOLUTIONS

NODE	Coordinates		BC	<- Nodal forces ->		<- Displacements ->		<-- Exponent format -->	
	X	Y		FX	FY	U	V	U	V
51	6.000	4.000	0	.00000	.00000	-.00190	-.00374	-.189837E-02	-.373734E-02
52	7.000	4.000	0	.00000	.00000	-.00174	-.00362	-.173610E-02	-.362375E-02
53	8.000	4.000	0	.00000	.00000	-.00133	-.00389	-.132756E-02	-.388564E-02
54	9.000	4.000	0	.00000	.00000	-.00073	-.00419	-.725399E-03	-.418808E-02
55	10.000	4.000	3	.45256	.00000	.00000	-.00432	.000000E+00	-.432017E-02
56	.000	5.000	3	.11972	.00000	.00000	-.19587	.000000E+00	-.195868E+00
57	1.000	5.000	0	.00000	.00000	.00611	-.16690	.611411E-02	-.166896E+00
58	2.000	5.000	0	.00000	.00000	.00240	-.11620	.239796E-02	-.116196E+00
59	3.000	5.000	0	.00000	.00000	-.00822	-.07710	-.821914E-02	-.771013E-01
60	4.000	5.000	0	.00000	.00000	-.01526	-.05692	-.152569E-01	-.569158E-01
61	5.000	5.000	0	.00000	.00000	-.00369	-.00547	-.368961E-02	-.546823E-02
62	6.000	5.000	0	.00000	.00000	-.00316	-.00435	-.316116E-02	-.434838E-02
63	7.000	5.000	0	.00000	.00000	-.00261	-.00451	-.260755E-02	-.450882E-02
64	8.000	5.000	0	.00000	.00000	-.00195	-.00510	-.195173E-02	-.509570E-02
65	9.000	5.000	0	.00000	.00000	-.00108	-.00568	-.108245E-02	-.568135E-02
66	10.000	5.000	3	-1.20314	.00000	.00000	-.00598	.000000E+00	-.597946E-02
67	.000	6.000	3	.51436	.00000	.00000	-.16517	.000000E+00	-.165170E+00
68	1.000	6.000	0	.00000	.00000	-.13501	-.11794	-.135013E+00	-.117943E+00
69	2.000	6.000	0	.00000	.00000	-.30288	-.03569	-.302878E+00	-.356947E-01
70	3.000	6.000	0	.00000	.00000	-.50967	.02907	-.509666E+00	.290655E-01
71	4.000	6.000	0	.00000	.00000	-.73677	.05199	-.736767E+00	.519897E-01
72	5.000	6.000	0	.00000	.00000	-.94127	.07037	-.941267E+00	.703683E-01
73	6.000	6.000	0	.00000	.00000	-1.06205	.00966	-.106205E+01	.965846E-02
74	7.000	6.000	0	.00000	.00000	-1.04896	-.09227	-.104896E+01	-.922719E-01
75	8.000	6.000	0	.00000	.00000	-.85868	-.21754	-.858683E+00	-.217542E+00
76	9.000	6.000	0	.00000	.00000	-.48956	-.32625	-.489555E+00	-.326247E+00
77	10.000	6.000	3	-.83295	.00000	.00000	-.38218	.000000E+00	-.382182E+00
78	.000	7.000	3	.51417	.00000	.00000	-.04125	.000000E+00	-.412518E-01
79	1.000	7.000	0	.00000	.00000	-.17286	.02998	-.172860E+00	.299828E-01
80	2.000	7.000	0	.00000	.00000	-.38372	.16006	-.383724E+00	.160057E+00
81	3.000	7.000	0	.00000	.00000	-.64474	.26830	-.644742E+00	.268299E+00
82	4.000	7.000	0	.00000	.00000	-.93703	.29985	-.937025E+00	.299852E+00
83	5.000	7.000	0	.00000	.00000	-1.20458	.25307	-.120458E+01	.253065E+00
84	6.000	7.000	0	.00000	.00000	-1.37838	.06149	-.137838E+01	.614948E-01
85	7.000	7.000	0	.00000	.00000	-1.39256	-.23750	-.139256E+01	-.237499E+00
86	8.000	7.000	0	.00000	.00000	-1.16723	-.60617	-.116723E+01	-.606170E+00
87	9.000	7.000	0	.00000	.00000	-.67942	-.93450	-.679417E+00	-.934499E+00
88	10.000	7.000	3	-.79583	.00000	.00000	-1.09962	.000000E+00	-.109962E+01
89	.000	8.000	3	.49778	.00000	.00000	.06495	.000000E+00	.649540E-01
90	1.000	8.000	0	.00000	.00000	-.10510	.16675	-.105096E+00	.166747E+00
91	2.000	8.000	0	.00000	.00000	-.25812	.35727	-.258122E+00	.357270E+00
92	3.000	8.000	0	.00000	.00000	-.47455	.52093	-.474551E+00	.520929E+00
93	4.000	8.000	0	.00000	.00000	-.73106	.56737	-.731062E+00	.567372E+00
94	5.000	8.000	0	.00000	.00000	-.97538	.45527	-.975382E+00	.455274E+00
95	6.000	8.000	0	.00000	.00000	-1.14651	.13621	-.114651E+01	.136213E+00
96	7.000	8.000	0	.00000	.00000	-1.18801	-.36518	-.118801E+01	-.365182E+00
97	8.000	8.000	0	.00000	.00000	-1.02649	-.99805	-.102649E+01	-.998046E+00
98	9.000	8.000	0	.00000	.00000	-.61232	-1.58580	-.612316E+00	-.158580E+01
99	10.000	8.000	3	-.82792	.00000	.00000	-1.88197	.000000E+00	-.188197E+01
100	.000	9.000	3	-1.95373	.00000	.00000	.03403	.000000E+00	.340282E-01

User description : NON-LINEAR RUN step number 1

NODAL SOLUTIONS

NODE	Coordinates		BC	<- Nodal forces ->		<- Displacements ->		<-- Exponent format -->	
	X	Y		FX	FY	U	V	U	V
101	1.000	9.000	0	.00000	.00000	.08682	.18672	.868211E-01	.186720E+00
102	2.000	9.000	0	.00000	.00000	.08813	.45697	.881320E-01	.456968E+00
103	3.000	9.000	0	.00000	.00000	.02952	.67963	.295229E-01	.679630E+00
104	4.000	9.000	0	.00000	.00000	-.07285	.75600	-.728458E-01	.756004E+00
105	5.000	9.000	0	.00000	.00000	-.19972	.61706	-.199717E+00	.617065E+00
106	6.000	9.000	0	.00000	.00000	-.32812	.22358	-.328124E+00	.223580E+00
107	7.000	9.000	0	.00000	.00000	-.42612	-.41728	-.426116E+00	-.417277E+00
108	8.000	9.000	0	.00000	.00000	-.44869	-1.23314	-.448690E+00	-1.23314E+01
109	9.000	9.000	0	.00000	.00000	-.33867	-2.05985	-.338666E+00	-2.05985E+01
110	10.000	9.000	3	6.13171	.00000	.00000	-2.50700	.000000E+00	-2.50700E+01
111	.000	10.000	4	2.81732	-1.73187	.00000	.00000	.000000E+00	.000000E+00
112	1.000	10.000	0	.00000	.00000	-.10052	.19823	-.100521E+00	.198228E+00
113	2.000	10.000	0	.00000	.00000	-.13284	.46193	-.132845E+00	.461932E+00
114	3.000	10.000	0	.00000	.00000	-.10213	.68572	-.102132E+00	.685719E+00
115	4.000	10.000	0	.00000	.00000	-.02718	.76168	-.271828E-01	.761677E+00
116	5.000	10.000	0	.00000	.00000	.07687	.62008	.768673E-01	.620080E+00
117	6.000	10.000	0	.00000	.00000	.19192	.22229	.191919E+00	.222292E+00
118	7.000	10.000	0	.00000	.00000	.29081	-.42481	.290812E+00	-.424808E+00
119	8.000	10.000	0	.00000	.00000	.33236	-1.25002	.332362E+00	-1.25002E+01
120	9.000	10.000	0	.00000	.00000	.24920	-2.06361	.249200E+00	-2.06361E+01
121	10.000	10.000	3	-6.60452	-5.00000	.00000	-2.64431	.000000E+00	-2.64431E+01

User description : NON-LINEAR RUN step number 1

ELT	Coordinates		Displacements		Strains			Stresses			Principal Stresses			
	X	Y	U	V	E-X	E-Y	E-XY	SIG-X	SIG-Y	SIG-XY	SIG-1	SIG-2	TH-1	TH-2
1	.50	.50	.0090	-.0189	.018050	-.037896	.002136	-.2359	-.2859	.0015	-.2359	-.2859	2	92
2	1.50	.50	.0226	-.0148	.009073	-.029599	.004631	-.2397	-.2880	.0049	-.2392	-.2885	6	96
3	2.50	.50	.0259	-.0096	-.002521	-.019255	.003782	-.2495	-.2951	.0072	-.2484	-.2962	9	99
5	4.50	.50	.0073	-.0028	-.015138	-.005636	.004167	-.2795	-.2361	.0093	-.2342	-.2814	78	168
6	5.50	.50	-.0002	-.0006	.000025	-.001128	-.000005	-.29	-1.25	.00	-.29	-1.25	0	90
7	6.50	.50	-.0002	-.0005	.000007	-.000989	-.000040	-.27	-1.10	-.02	-.27	-1.10	-1	89
8	7.50	.50	-.0002	-.0005	.000031	-.000925	-.000061	-.22	-1.02	-.03	-.22	-1.02	-2	88
9	8.50	.50	-.0001	-.0005	.000074	-.000913	-.000054	-.17	-.99	-.02	-.17	-.99	-2	88
10	9.50	.50	-.0001	-.0005	.000106	-.000918	-.000022	-.14	-.99	-.01	-.14	-.99	-1	89
11	.50	1.50	.0083	-.0565	.016643	-.037215	.006614	-.2441	-.2945	.0050	-.2436	-.2949	6	96
12	1.50	1.50	.0210	-.0445	.008769	-.029884	.014319	-.2503	-.2936	.0135	-.2465	-.2974	16	106
13	2.50	1.50	.0246	-.0293	-.001723	-.020117	.012329	-.2577	-.2919	.0184	-.2497	-.2999	24	114
14	3.50	1.50	.0191	-.0187	-.009222	-.012780	.006305	-.2652	-.2796	.0171	-.2539	-.2910	34	124
15	4.50	1.50	.0070	-.0085	-.014901	-.005683	.012969	-.2719	-.2426	.0185	-.2336	-.2808	64	154
16	5.50	1.50	-.0004	-.0017	.000027	-.001095	-.000012	-.27	-1.21	-.01	-.27	-1.21	0	90
17	6.50	1.50	-.0004	-.0015	.000021	-.000968	-.000135	-.25	-1.07	-.06	-.24	-1.07	-4	86
18	7.50	1.50	-.0004	-.0014	.000067	-.000928	-.000207	-.18	-1.01	-.09	-.17	-1.02	-6	84
19	8.50	1.50	-.0002	-.0014	.000135	-.000945	-.000184	-.11	-1.01	-.08	-.11	-1.02	-5	85
20	9.50	1.50	-.0001	-.0014	.000182	-.000970	-.000072	-.07	-1.03	-.03	-.07	-1.03	-2	88
21	.50	2.50	.0075	-.0935	.015016	-.036764	.011390	-.2580	-.3087	.0088	-.2565	-.3102	10	100
22	1.50	2.50	.0191	-.0745	.008083	-.029973	.024080	-.2648	-.3013	.0196	-.2563	-.3098	24	114
23	2.50	2.50	.0226	-.0499	-.001062	-.021047	.020966	-.2695	-.2920	.0233	-.2549	-.3066	32	122
24	3.50	2.50	.0180	-.0319	-.008102	-.013646	.011390	-.2683	-.2735	.0238	-.2470	-.2948	42	132
25	4.50	2.50	.0066	-.0143	-.014753	-.005875	.022036	-.2729	-.2480	.0205	-.2365	-.2844	61	151
26	5.50	2.50	-.0008	-.0027	.000023	-.001029	-.000045	-.26	-1.14	-.02	-.26	-1.14	-1	89
27	6.50	2.50	-.0008	-.0024	.000040	-.000913	-.000290	-.21	-1.00	-.12	-.19	-1.02	-8	82
28	7.50	2.50	-.0007	-.0023	.000147	-.000934	-.000439	-.10	-1.00	-.18	-.06	-1.03	-11	79
29	8.50	2.50	-.0005	-.0024	.000267	-.001021	-.000370	.01	-1.06	-.15	.04	-1.08	-8	82
30	9.50	2.50	-.0002	-.0024	.000341	-.001085	-.000142	.08	-1.11	-.06	.08	-1.11	-3	87
31	.50	3.50	.0067	-.1301	.013387	-.036422	.016342	-.2738	-.3252	.0122	-.2711	-.3279	13	103
32	1.50	3.50	.0164	-.1039	.006115	-.028805	.031835	-.2796	-.3106	.0235	-.2669	-.3233	28	118
33	2.50	3.50	.0185	-.0707	-.001907	-.020591	.025290	-.2822	-.2955	.0261	-.2619	-.3158	38	128
34	3.50	3.50	.0141	-.0462	-.006990	-.014903	.011517	-.2821	-.2688	.0244	-.2502	-.3007	53	143
35	4.50	3.50	.0046	-.0206	-.012066	-.006911	.029753	-.2568	-.2308	.0185	-.2211	-.2664	63	153
36	5.50	3.50	-.0015	-.0037	-.000011	-.000917	-.000118	-.27	-1.02	-.05	-.26	-1.03	-4	86
37	6.50	3.50	-.0014	-.0033	.000106	-.000811	-.000631	-.1080	-.8721	-.2627	-.0264	-.9537	-17	73
38	7.50	3.50	-.0012	-.0033	.000305	-.000968	-.000795	.07	-.99	-.33	.16	-1.09	-16	74
39	8.50	3.50	-.0008	-.0035	.000478	-.001158	-.000624	.21	-1.15	-.26	.26	-1.20	-10	80
40	9.50	3.50	-.0003	-.0036	.000583	-.001281	-.000238	.29	-1.26	-.10	.30	-1.27	-4	86
41	.50	4.50	.0046	-.1648	.009287	-.033085	.021415	-.2888	-.3426	.0148	-.2850	-.3464	14	104
42	1.50	4.50	.0095	-.1299	.000452	-.023285	.034770	-.2914	-.3208	.0264	-.2758	-.3364	30	120
43	2.50	4.50	.0064	-.0888	-.006745	-.015639	.018310	-.2959	-.3037	.0288	-.2707	-.3289	41	131
44	3.50	4.50	-.0004	-.0603	-.006831	-.013358	-.002498	-.2820	-.2584	.0230	-.2443	-.2961	59	149
45	4.50	4.50	-.0033	-.0276	.001064	-.007087	.032890	-.2435	-.2076	.0117	-.2041	-.2470	74	164
46	5.50	4.50	-.0027	-.0045	.000243	-.000739	-.000556	.0651	-.7532	-.2316	.1261	-.8142	-15	75
47	6.50	4.50	-.0024	-.0041	.000358	-.000748	-.001091	.19	-.73	-.45	.38	-.92	-22	68
48	7.50	4.50	-.0019	-.0043	.000532	-.001048	-.001172	.30	-1.02	-.49	.46	-1.18	-18	72
49	8.50	4.50	-.0013	-.0047	.000736	-.001352	-.000935	.44	-1.30	-.39	.53	-1.38	-12	78
50	9.50	4.50	-.0005	-.0050	.000904	-.001576	-.000394	.57	-1.50	-.16	.58	-1.51	-5	85

User description : NON-LINEAR RUN step number 1

ELT	Coordinates		Displacements		Strains			Stresses			Principal Stresses				NO
	X	Y	U	V	E-X	E-Y	E-XY	SIG-X	SIG-Y	SIG-XY	SIG-1	SIG-2	TH-1	TH-2	
51	.50	5.50	-.0322	-.1615	-.064449	.039825	-.032464	-.3637	-.3104	-.0158	-.3061	-.3680	-.75	15	2
52	1.50	5.50	-.1073	-.1092	-.085791	.064727	-.156727	-.3445	-.3147	-.0288	-.2972	-.3620	-.59	31	2
53	2.50	5.50	-.2046	-.0500	-.108703	.093334	-.351433	-.3311	-.3072	-.0322	-.2848	-.3534	-.55	35	2
54	3.50	5.50	-.3175	-.0132	-.117069	.107536	-.589923	-.3294	-.3079	-.0344	-.2826	-.3547	-.54	36	2
55	4.50	5.50	-.4242	.0150	-.096466	.092371	-.794630	-.3203	-.3037	-.0358	-.2753	-.3488	-.52	38	2
56	5.50	5.50	-.5025	.0176	-.060129	.044922	-1.038030	-.52	-.51	-.05	-.46	-.57	-.47	43	2
57	6.50	5.50	-.5292	-.0229	.006822	-.036878	-1.103670	-.72	-.73	-.07	-.65	-.80	-.43	47	2
58	7.50	5.50	-.4781	-.0799	.095469	-.150105	-1.014472	-.99	-1.03	-.09	-.91	-1.10	-.39	51	2
59	8.50	5.50	-.3378	-.1386	.184998	-.266506	-.727247	-1.22	-1.33	-.11	-1.16	-1.40	-.31	59	2
60	9.50	5.50	-.1227	-.1800	.245319	-.348385	-.723233	-1.36	-1.59	-.07	-1.34	-1.61	-.15	75	2
61	.50	6.50	-.0770	-.0736	-.153936	.135922	.040307	-.3466	-.2815	.0058	-.2810	-.3472	.85	175	2
62	1.50	6.50	-.2486	.0091	-.189365	.171839	.046815	-.3649	-.2977	.0075	-.2968	-.3657	.84	174	2
63	2.50	6.50	-.4603	.1054	-.233903	.217493	-.021460	-.3808	-.3108	.0025	-.3107	-.3809	.88	178	2
64	3.50	6.50	-.7070	.1623	-.259692	.243548	-.140429	-.4003	-.3301	-.0087	-.3290	-.4014	-.83	7	2
65	4.50	6.50	-.9549	.1688	-.236027	.215279	-.245989	-.4510	-.3880	-.0260	-.3787	-.4604	-.70	20	2
66	5.50	6.50	-1.1466	.0986	-.147292	.117267	-.415958	-.55	-.51	-.05	-.48	-.58	-.55	35	2
67	6.50	6.50	-1.2205	-.0647	-.000546	-.046695	-.530420	-.72	-.78	-.06	-.68	-.82	-.32	58	2
68	7.50	6.50	-1.1169	-.2884	.207806	-.266927	-.573039	-.89	-1.04	-.05	-.88	-1.06	-.16	74	2
69	8.50	6.50	-.7987	-.5211	.428469	-.498439	-.467720	-1.08	-1.30	-.03	-1.08	-1.30	-.8	82	2
70	9.50	6.50	-.2922	-.6856	.584486	-.662844	-.205459	-1.24	-1.49	-.01	-1.24	-1.49	-.3	87	2
71	.50	7.50	-.0695	.0551	-.138978	.121485	.120396	-.3382	-.2758	.0101	-.2742	-.3398	.81	171	2
72	1.50	7.50	-.2300	.1785	-.181945	.166988	.256982	-.3511	-.2936	.0187	-.2881	-.3567	.74	164	2
73	2.50	7.50	-.4403	.3266	-.238723	.224922	.283847	-.3719	-.3148	.0214	-.3077	-.3790	.72	162	2
74	3.50	7.50	-.6968	.4141	-.274397	.260075	.227074	-.3925	-.3317	.0196	-.3259	-.3983	.74	164	2
75	4.50	7.50	-.9620	.3939	-.255937	.234864	.138138	-.4601	-.3863	.0157	-.3831	-.4633	.78	168	2
76	5.50	7.50	-1.1762	.2265	-.172463	.138463	-.024785	-.57	-.47	.01	-.47	-.57	.83	173	2
77	6.50	7.50	-1.2764	-.1012	-.027840	-.026483	-.181988	-.67	-.80	-.02	-.67	-.81	-.9	81	2
78	7.50	7.50	-1.1936	-.5517	.193424	-.259780	-.328126	-.92	-1.10	-.01	-.91	-1.10	-.2	88	2
79	8.50	7.50	-.8714	-1.0311	.450993	-.521587	-.354121	-1.09	-1.32	-.01	-1.09	-1.32	-.1	89	2
80	9.50	7.50	-.3229	-1.3755	.645866	-.716824	-.197096	-1.19	-1.43	.00	-1.19	-1.43	-.1	89	2
81	.50	8.50	-.0046	.1131	-.009137	-.005476	.223201	-.2626	-.2429	.0240	-.2268	-.2787	.56	146	2
82	1.50	8.50	-.0471	.2919	-.075358	.059836	.499472	-.3731	-.3517	.0372	-.3238	-.4011	.53	143	2
83	2.50	8.50	-.1538	.5037	-.137519	.129200	.618325	-.3289	-.3084	.0345	-.2827	-.3546	.53	143	2
84	3.50	8.50	-.3122	.6310	-.179440	.173667	.642553	-.3180	-.2974	.0332	-.2730	-.3425	.54	144	2
85	4.50	8.50	-.4948	.5989	-.185596	.175212	.591422	-.3641	-.3425	.0362	-.3155	-.3910	.53	143	2
86	5.50	8.50	-.6624	.3580	-.149768	.124579	.440753	-.4935	-.4763	.0472	-.4369	-.5329	.50	141	2
87	6.50	8.50	-.7722	-.1057	-.069745	.017636	.219016	-.74	-.76	.07	-.68	-.82	.41	141	2
88	7.50	8.50	-.7723	-.7534	.069472	-.143593	-.054514	-.96	-1.09	.07	-.93	-1.12	.22	112	2
89	8.50	8.50	-.6065	-1.4692	.262100	-.354571	-.281504	-1.26	-1.50	.04	-1.25	-1.50	.8	98	2
90	9.50	8.50	-.2377	-2.0087	.475491	-.549540	-.234837	-1.14	-1.36	.01	-1.14	-1.36	.2	92	2
91	.50	9.50	-.0034	.1047	-.006850	-.011260	.081789	-1.04	-1.20	1.51	.40	-2.63	.43	133	2
92	1.50	9.50	-.0146	.3260	-.015507	.008236	.062817	-.89	-.01	1.16	.79	-1.69	.55	145	2
93	2.50	9.50	-.0293	.5711	-.013948	.005526	.046909	-.88	-.16	.87	.42	-1.46	.56	146	2
94	3.50	9.50	-.0432	.7208	-.013710	.005881	.033170	-.85	-.12	.61	.23	-1.20	.60	150	2
95	4.50	9.50	-.0557	.6887	-.011411	.004344	.020856	-.7280	-.1445	.3862	.0478	-.9202	.64	154	2
96	5.50	9.50	-.0648	.4208	-.006677	.000863	.002677	-.4985	-.2192	.0496	-.2107	-.5071	.80	170	2
97	6.50	9.50	-.0679	-.0991	.000450	-.004410	-.025494	-.1544	-.3344	-.4721	.2362	-.7250	-.40	50	2
98	7.50	9.50	-.0629	-.8313	.009488	-.012208	-.071549	.23	-.57	-1.32	1.22	-1.55	-.37	53	2
99	8.50	9.50	-.0514	-1.6517	.013431	-.010323	-.135688	.63	-.25	-2.51	2.74	-2.36	-.40	50	2
100	9.50	9.50	-.0224	-2.3187	.044733	-.070538	-.219996	.54	-3.73	-4.07	3.01	-6.19	-.31	59	2

QUAD -- 2 D FINITE ELEMENT PACKAGE -- Ver 4.00 -- GEMCOM (PTY) LTD.

Module 7.01

User description : NON-LINEAR RUN step number 1

Page 19
8/24/89 9:13:22

Details for 2 perimeters follow:

Perimeter number 1 contains 5 nodes

Description : Test perimeter NUMBER 1

6 8 19 17 6

Perimeter number 2 contains 5 nodes

Description : Test perimeter NUMBER 2

17 19 30 28 17

Element/subregion connectivity:

From Element	Description of material	Youngs Modulus	Poissons Ratio	Subregion Number
1	SOFT	10.0	.350	1
6	HARD	1000.0	.200	2
11	SOFT	10.0	.350	1
16	HARD	1000.0	.200	2
21	SOFT	10.0	.350	1
26	HARD	1000.0	.200	2
31	SOFT	10.0	.350	1
36	HARD	1000.0	.200	2
41	SOFT	10.0	.350	1
46	HARD	1000.0	.200	2
51	SOFT	10.0	.350	1
91	TOP BEAM	50.0	.350	3

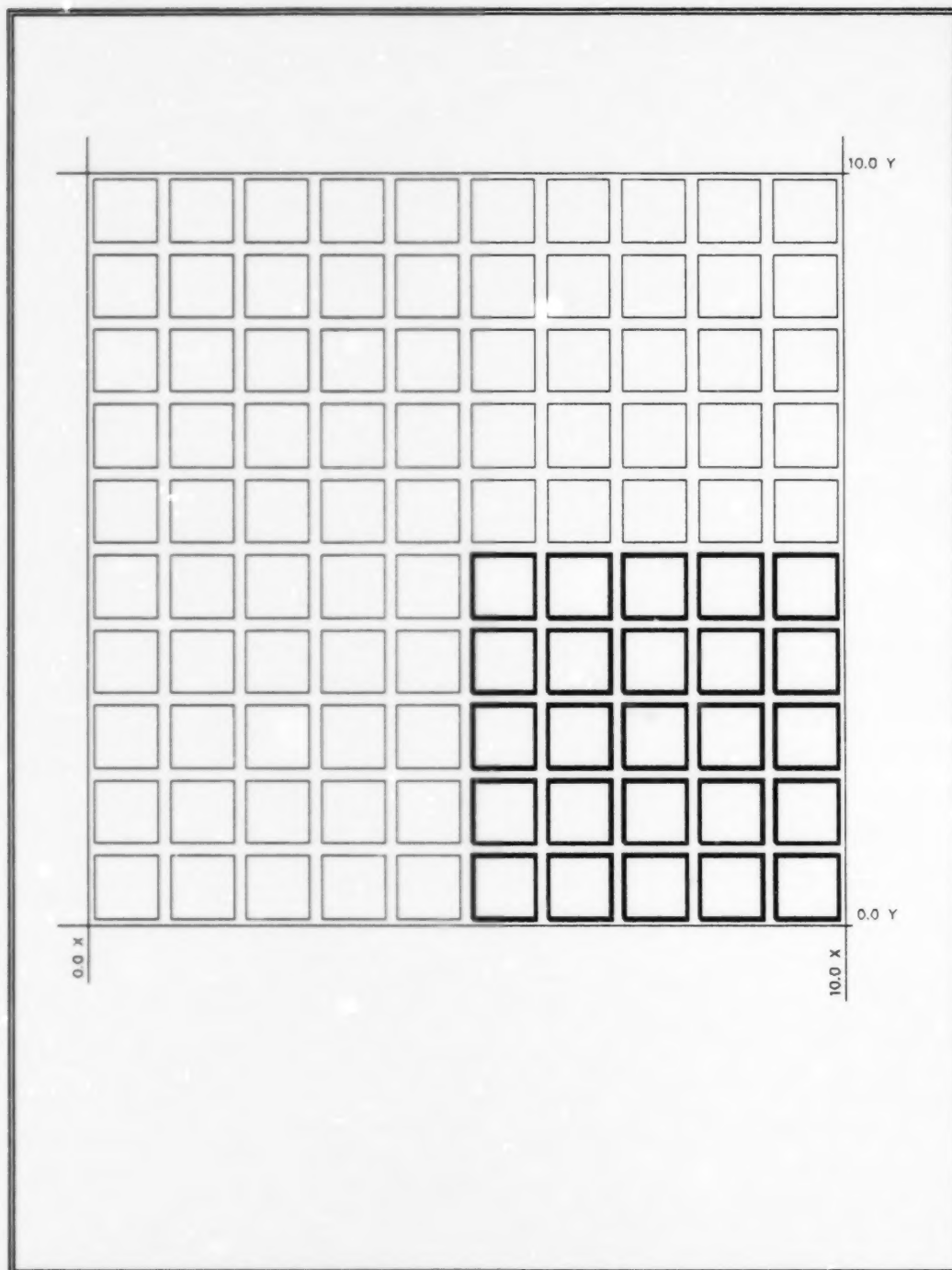
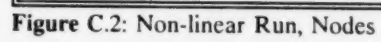


Figure C.1: Non-linear Run, Original Mesh



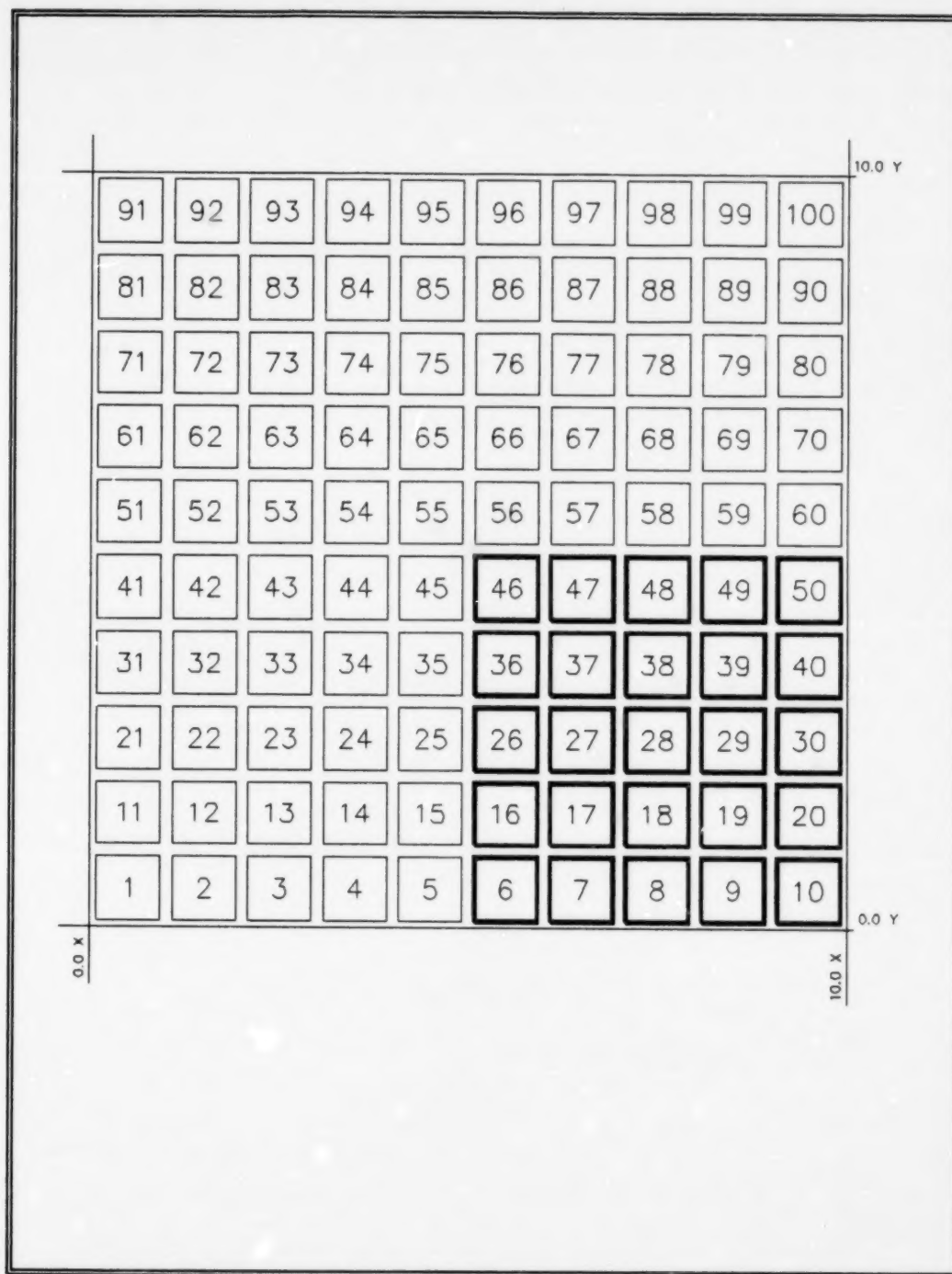


Figure C.3: Non-linear Run, Elements

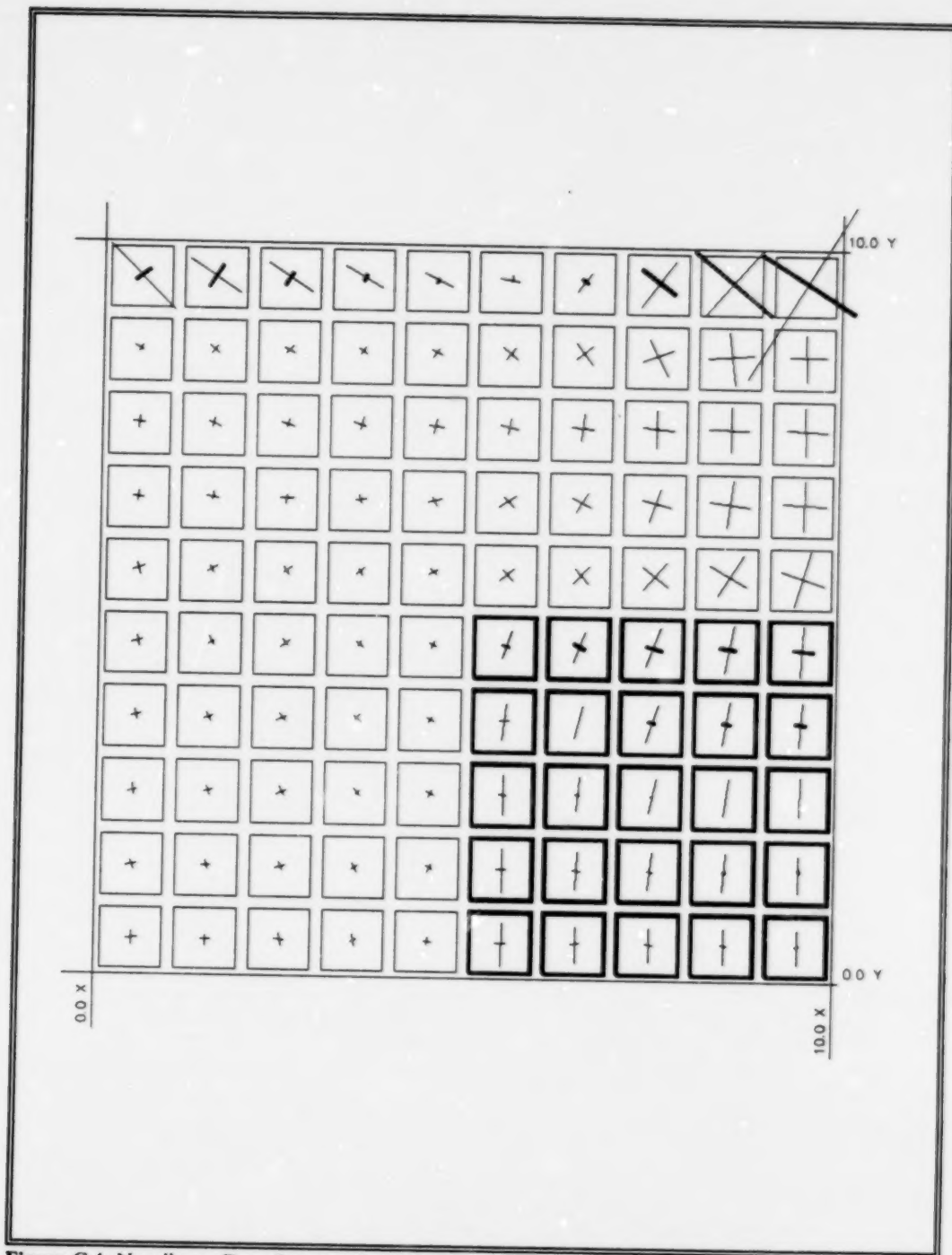


Figure C.4: Non-linear Run, Stresses (bold lines are tension)

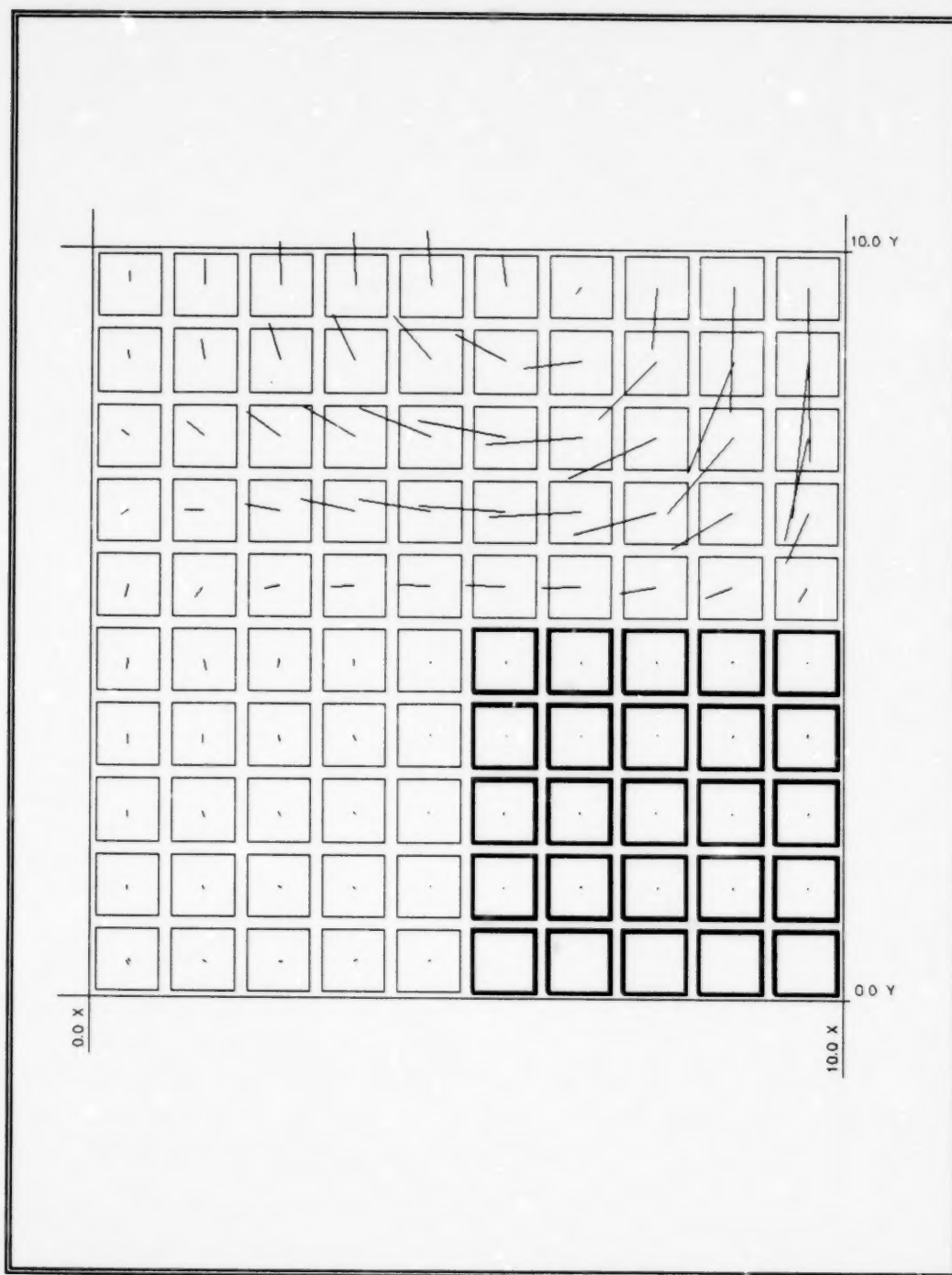


Figure C.5: Non-linear Run, Displacement

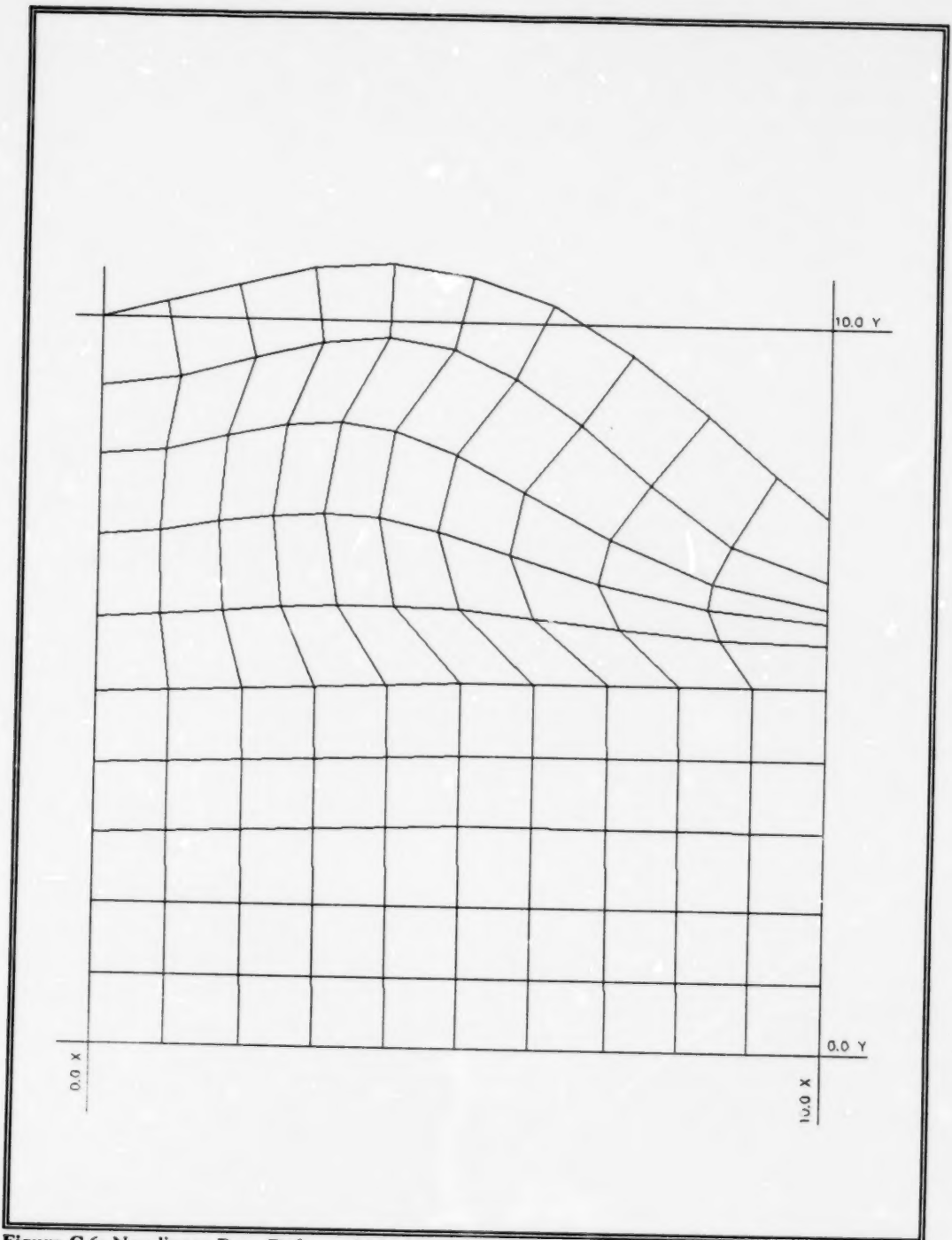


Figure C.6: Non-linear Run, Deformed Mesh